

**Annual Report to Alaska Department of Environmental Conservation**

# **Commitment to Corrosion Monitoring Year 2003**

Prepared by

Corrosion, Inspection and Chemicals (CIC) Group  
BP Exploration (Alaska), Inc.

March 2004





# **Commitment to Corrosion Monitoring**

**Year 2003**





## Foreword

This is the fourth annual report that meets the commitment made by BPXA to the State of Alaska to provide a regular review of BPXA's corrosion monitoring and management practices for non-common carrier pipelines on the North Slope. The contents of this report reflect the Work Plan<sup>1</sup> agreed jointly between BPXA, Phillips and ADEC, the Guide for Performance Metric Reporting<sup>2</sup>, and feedback from previous ADEC reports. The report is divided into 2 main parts.

**Part 1** contains information regarding the BPXA operated fields within the Greater Prudhoe Bay (GPB) Performance Unit. This consists principally of fluids produced from Prudhoe Bay, Lisburne, Point McIntyre and Niakuk field areas but also includes smaller volumes of fluids from satellite accumulations.

**Part 2** contains information regarding the BPXA operated fields within the Alaska Consolidated Team (ACT) Performance Unit. This consists principally of fluids from Endicott, Badami, Milne Point and Northstar field areas. As with GPB, several smaller satellite accumulations are also produced through ACT facilities.

The report provides an overview of the corrosion management process, and provides data and discussion of the corrosion control, monitoring, inspection and fitness-for-service programs. These individual programs, in concert, form the core of the integrity/corrosion management system designed to deliver our corporate goal of no accidents, no harm to people and no damage to the environment<sup>3</sup>. The program also reflects the core values of BP: innovation, performance driven, environmental leadership and progressive.

**Innovation** is evident in several areas, from the development of more effective corrosion inhibitors and corrosion inhibition programs, to the application of new inspection technologies. These innovations are only made possible by working closely with partners, major suppliers and the regulatory community, to bring the best available technology to Alaskan oilfields.

**Performance** management and the drive for improved performance are central to all aspects of the corrosion management program. This report demonstrates an on-going effort to improve corrosion management. Over the last decade corrosion rates have been reduced by almost a factor of 10 in the cross-country pipelines that transport a mixture of oil, water and gas. Consistent with the pledge to report openly both good and bad performance, the report highlights areas for improvement and the plans in-place to deliver performance improvement.

---

<sup>1</sup> Appendix 2 (a) 2000 Work Plan

<sup>2</sup> Appendix 2 (b) Guide for Performance Metric Reporting

<sup>3</sup> BP HSE Policy Statement, EJP Browne, Group CEO, January, 1999, <http://www.bp.com/>

**Environmental** protection and corrosion management are closely linked. The improvements in corrosion management have resulted in lower corrosion rates and a lower risk of loss of containment. Opportunities to improve environmental performance still exist and the investment in continuous corrosion inhibitor injection at Drill Site Niakuk as well as the continued effort on our external corrosion inspection program is evidence of this on-going commitment.

**Progressive** evolution of the corrosion management programs is an on-going activity driven by changing field conditions and the desire to improve performance. Progress involves the continued refinement of the existing programs, but also, the development and implementation of new programs and corrosion management technologies.

The current corrosion management process has delivered a significantly improved level of corrosion control that has reduced corrosion rates in the cross-country flow lines by a factor of 10 in the last 10 years. Notwithstanding the successes of the last 10 years the corrosion management program must remain focused on the future in order to maintain the current level of control and, where necessary, implement the actions necessary to improve performance.

The continuous improvement of the corrosion management programs delivered over the last 10 years has enabled BPXA to deliver the programs strategic objectives of:

- Minimizing the health, safety and environmental impacts of loss of containment due to corrosion
- Providing a fit-for-service infrastructure for the remainder of field life
- Producing satellite accumulations through existing equipment and pipe-work
- Providing an infrastructure capable of supporting gas sales in the future

In addition, with the information in this report, BPXA intends to build a healthy relationship with the North Slope stakeholders through consultation, open reporting and striving to raise the standards of the industry.

BP Exploration (Alaska) Inc.  
March 2004

## Table of Contents

Foreword .....	i
Table of Contents .....	iii
Table of GPB Figures .....	vi
Table of ACT Figures .....	vii
Table of GPB Tables .....	viii
Table of ACT Tables.....	ix
Section A Charter Agreement – Corrosion Related Commitments .....	3
Section A.1 Project Achievements .....	3
Section A.2 Annual Charter Timetable .....	3
Part 1 – Greater Prudhoe Bay Performance Unit .....	5
Section B Corrosion Monitoring Activities.....	7
Section B.1 Corrosion Management System.....	7
Section B.1.1 Process .....	8
Section B.1.2 Objectives and Targets .....	9
Section B.1.3 Implementation .....	9
Section B.1.4 Evaluation .....	10
Section B.1.5 Corrective Action .....	10
Section B.2 Corrosion and Inspection Data Management.....	11
Section B.2.1 MIMIR Database.....	11
Section B.2.2 Historical Data.....	12
Section B.3 Inspection and Corrosion Monitoring Activity Level .....	12
Section B.3.1 Inspection Activity .....	12
Section B.3.2 Corrosion Monitoring Activity .....	15
Section B.4 Corrosion Monitoring Activity Summary .....	18
Section C Weight Loss Coupons and Probes .....	45
Section C.1 Three Phase Production Systems .....	45
Section C.1.1 Cross Country Flow Line Coupons .....	45
Section C.1.2 Well Line Coupons .....	47
Section C.1.3 Three Phase Coupon Program Summary .....	48
Section C.2 Water Injection Systems.....	48
Section C.2.1 Water Injection System Flow Lines .....	48
Section C.2.2 Produced Water Injection Well Lines.....	49
Section C.2.3 Seawater Injection Well Lines.....	52
Section C.3 Electrical Resistance Probes.....	57
Section C.4 1992 to Date Summary .....	58
Section C.4.1 System by System Summary .....	58
Section C.4.2 Aggregate Summary .....	63
Section D Chemical Optimization Activities .....	67
Section D.1 Chemical Optimization .....	67
Section D.2 Corrosion Inhibitor Development.....	67
Section D.3 Corrosion Inhibitor Testing .....	70

Section D.4	Field Wide Corrosion Inhibitor Deployment .....	71
Section D.5	Corrosion Inhibitor Usage and Concentration .....	72
Section D.6	Corrosion Inhibition and Corrosion Rate Correlation .....	74
Section D.7	ER Probe and Corrosion Inhibitor Response .....	76
Section D.8	Chemical Optimization Summary .....	77
Section E	External/Internal Inspection .....	81
Section E.1	External Inspection .....	81
Section E.1.1	External Inspection Program Results .....	83
Section E.1.2	Cased Piping Survey Results .....	85
Section E.1.3	Excavation History .....	88
Section E.1.4	External Program Summary .....	89
Section E.2	Internal inspection .....	89
Section E.2.1	Internal Inspection Program – Scope .....	89
Section E.2.2	Internal Inspection Program Results .....	90
Section E.3	Fitness for Service Assessment .....	92
Section E.4	Correlation Between Inspection and Corrosion Monitoring .....	97
Section E.5	In-line Inspection .....	98
Section E.6	Inspection Summary .....	101
Section F	Repair Activities .....	109
Section G	Corrosion and Structural Related Spills and Incidents .....	117
Section G.1	Corrosion Related Leaks .....	117
Section G.2	Structural Integrity Issues .....	119
Section G.2.1	Waking Speed Survey .....	119
Section G.2.2	Routine Surveillance .....	120
Section G.2.3	2003 Summary .....	120
Section H	Corrosion Monitoring and Inspection Goals .....	125
Section H.1	2003 Corrosion and Inspection Goals Reviewed .....	125
Section H.1.1	Corrosion Monitoring .....	125
Section H.1.2	Inspection Programs .....	126
Section H.1.3	Chemical Optimization .....	126
Section H.1.4	Program Reviews .....	126
Section H.1.5	2003 Corrective Actions .....	127
Section H.2	2004 Corrosion Management Goals .....	128
Section H.2.1	Corrosion Monitoring .....	128
Section H.2.2	Inspection Programs .....	128
Section H.2.3	Chemical Optimization .....	129
Section H.2.4	Program Improvements and Modification .....	129
Part 2 – Alaska Consolidated Team Performance Unit .....		131
Section B	Corrosion Monitoring Activities .....	133
Section B.1	Endicott .....	134
Section B.2	Milne Point .....	136
Section B.3	Northstar .....	136
Section B.4	Badami .....	137
Section B.5	Overall Inspection Activity Level .....	137
Section C	Weight Loss Coupons .....	139
Section C.1	Endicott .....	139
Section C.2	Milne Point .....	140
Section C.3	Northstar .....	141
Section C.4	Badami .....	141



Section D	Corrosion Mitigation Activities.....	142
Section D.1	Endicott.....	142
Section D.2	Milne Point .....	144
Section D.3	Northstar.....	145
Section D.4	Badami.....	145
Section E	External/Internal Inspection.....	146
Section E.1	External Inspection .....	146
Section E.1.1	Endicott .....	146
Section E.1.2	Milne Point .....	146
Section E.1.3	Badami .....	147
Section E.1.4	Northstar .....	147
Section E.2	Internal Corrosion Inspection.....	148
Section E.2.1	Endicott .....	148
Section E.2.2	Milne Point .....	149
Section E.2.3	Badami .....	152
Section E.2.4	Northstar .....	152
Section F	Repair Activities .....	154
Section G	Corrosion and Structural Related Spills and Incidents .....	155
Section H	2004 Corrosion Monitoring and Inspection Goals.....	157
Section H.1	Endicott.....	157
Section H.2	Milne Point .....	157
Section H.3	Northstar.....	157
Section H.4	Badami.....	158
Appendix 1.....		159
Appendix 2.....		163
2000 Work Plan .....		165
Guide for Performance Metric Reporting.....		169
Appendix 3.....		175
Appendix 4.....		181
Appendix 5.....		185
Introduction .....		187

## Table of GPB Figures

GPB FIGURE B.1 OVERVIEW OF THE CORROSION MANAGEMENT PROCESS .....	8
GPB FIGURE B.2 INTERNAL AND EXTERNAL INSPECTION ACTIVITY FOR FLOW AND WELL LINES .....	13
GPB FIGURE B.3 INTERNAL AND EXTERNAL INSPECTION ACTIVITY SUMMARY BY FLOW/WELL LINE .....	14
GPB FIGURE B.4 CORROSION MONITORING ACTIVITY STATISTICS BY EQUIPMENT .....	17
GPB FIGURE C.1 FLOW LINE OIL SERVICE CORROSION RATE TREND .....	46
GPB FIGURE C.2 CORRELATION BETWEEN FLOW LINE CORROSION RATE AND PERCENTAGE CONFORMANCE .....	46
GPB FIGURE C.3 WELL LINE OIL SERVICE CORROSION RATE TREND .....	47
GPB FIGURE C.4 FLOW LINE PW/SW SERVICE CORROSION RATE TREND .....	49
GPB FIGURE C.5 CORROSION RATES FOR 100% PW SYSTEM .....	50
GPB FIGURE C.6 CORROSION RATES FOR MAJORITY PW SYSTEM .....	51
GPB FIGURE C.7 COMPARISON OF CORROSION RATES FOR 100% AND MAJORITY PW .....	51
GPB FIGURE C.8 CORROSION RATE FOR 100% SEAWATER SYSTEM .....	53
GPB FIGURE C.9 CORROSION RATES FOR MAJORITY SW SYSTEM .....	53
GPB FIGURE C.10 COMPARISON OF CORROSION RATES FOR 100% AND MAJORITY SW SYSTEM .....	54
GPB FIGURE C.11 DISSOLVED OXYGEN CONTROL PERFORMANCE FOR THE SEAWATER SYSTEM .....	54
GPB FIGURE C.12 BIOCIDES TREATMENT CONCENTRATION AND CORROSION RATE .....	56
GPB FIGURE C.13 AVERAGE CORROSION RATE VS. EFFECTIVE CONCENTRATION, 2001 - 2003 .....	56
GPB FIGURE C.14 EQUIPMENT MONITORED USING ER PROBES .....	58
GPB FIGURE C.15 FLOW LINE CORROSION COUPON SUMMARY BY EQUIPMENT AND SERVICE .....	59
GPB FIGURE C.16 WELL LINE AVERAGE CORROSION RATE SUMMARY BY EQUIPMENT AND SERVICE .....	60
GPB FIGURE C.17 WELL LINE %<2MPY SUMMARY BY EQUIPMENT AND SERVICE .....	60
GPB FIGURE C.18 WLC CORROSION RATE DIFFERENCE BY SERVICE AND TYPE .....	61
GPB FIGURE C.19 GPB AGGREGATE PERFORMANCE .....	63
GPB FIGURE D.1 ER PROBE CHEMICAL OPTIMIZATION TEST .....	69
GPB FIGURE D.2 CORROSION COUPONS PULLED AFTER AN 'UNSUCCESSFUL' CHEMICAL TRIAL .....	70
GPB FIGURE D.3 NUMBER OF WELL LINE AND FLOW LINE TESTS .....	71
GPB FIGURE D.4 FIELD WIDE CHEMICAL USAGE .....	74
GPB FIGURE D.5 AVERAGE CORROSION RATE VERSUS INHIBITOR CONCENTRATION .....	75
GPB FIGURE D.6 CORROSION INHIBITOR CONCENTRATION VS. AVERAGE CORROSION RATE .....	75
GPB FIGURE D.7 CORROSION INHIBITOR CONCENTRATION VS. CORROSION RATE .....	76
GPB FIGURE E.1 EXTERNAL CORROSION ACTIVITY AND DETECTION SUMMARY .....	85
GPB FIGURE E.2 CUMULATIVE CASED PIPE INSPECTION ACTIVITY .....	87
GPB FIGURE E.3 CASED PIPING INSPECTION HISTORY BY DETECTION METHOD .....	87
GPB FIGURE E.4 FLOW LINE INTERNAL INSPECTION INCREASE BY SERVICE .....	91
GPB FIGURE E.5 WELL LINE INTERNAL INSPECTION INCREASE BY SERVICE .....	92
GPB FIGURE E.6 MAOP VERSUS REMAINING WALL THICKNESS .....	94
GPB FIGURE E.7 FITNESS-FOR-SERVICE ENVELOPE BASED ON BP SPC-PP-00090 .....	96
GPB FIGURE E.8 CORRELATION OF CORROSION RATE AND %INCREASES, 3-PHASE PRODUCTION .....	98
GPB FIGURE E.9 HISTORICAL SMART PIG ACTIVITY AND CORROSION RATE .....	100
GPB FIGURE F.1 REPAIRS BY SERVICE .....	110
GPB FIGURE F.2 REPAIRS BY DAMAGE MECHANISM .....	110
GPB FIGURE F.3 REPAIRS BY EQUIPMENT .....	111
GPB FIGURE G.1 HISTORICAL CORROSION LEAKS AND SAVES BY LINE TYPE .....	118
GPB FIGURE G.2 HISTORICAL CORROSION LEAKS AND SAVES .....	119

## Table of ACT Figures

ACT FIGURE C.1 CORROSION COUPON DATA FROM ENDICOTT 1995-2003 .....	139
ACT FIGURE C.2 CORROSION COUPON DATA FROM MPU 1995-2003.....	140
ACT FIGURE D.1 ENDICOTT IIWL UT READINGS THROUGH 2003 .....	142
ACT FIGURE D.2 MILNE POINT PRODUCED WATER CORROSION RATE TREND .....	144
ACT FIGURE E.1 DETECTION OF INTERNAL CORROSION OF WELL LINES BY INSPECTION AT ENDICOTT 2003..	148
ACT FIGURE E.2 DETECTION OF INTERNAL CORROSION OF FLOW LINE BY INSPECTION AT ENDICOTT 2003 ...	149
ACT FIGURE E.3 DETECTION OF INTERNAL CORROSION OF FLOW LINES BY INSPECTION AT MPU 2003.....	150
ACT FIGURE E.4 DETECTION OF INTERNAL CORROSION OF WELL LINES BY INSPECTION .....	151

## Table of GPB Tables

GPB TABLE B.1 CORROSION MANAGEMENT PROCESS .....	9
GPB TABLE B.2 CORROSION MANAGEMENT FEEDBACK CYCLES .....	10
GPB TABLE B.3 DATABASE RECORD ACCUMULATION RATE .....	12
GPB TABLE B.4 INTERNAL AND EXTERNAL INSPECTION ACTIVITY BREAKDOWN .....	13
GPB TABLE B.5 INTERNAL AND EXTERNAL INSPECTION ACTIVITY SUMMARY BY FLOW/WELL LINE .....	14
GPB TABLE B.6 CORROSION MONITORING LOCATIONS BY EQUIPMENT AND SERVICE .....	15
GPB TABLE B.7 CORROSION MONITORING ACTIVITY STATISTICS BY EQUIPMENT TYPE .....	16
GPB TABLE B.8 ACTIVE ER PROBE LOCATIONS .....	17
GPB TABLE B.9 CORROSION MANAGEMENT SYSTEM .....	19
GPB TABLE B.10 CORROSION MANAGEMENT SYSTEM ELEMENT – MONITORING .....	21
GPB TABLE B.11 MONITORING PROGRAM TECHNIQUES .....	29
GPB TABLE B.12 CORROSION MONITORING TECHNIQUES – BENEFITS AND LIMITATIONS .....	35
GPB TABLE B.13 PROCESS MONITORING TECHNIQUES – BENEFITS AND LIMITATIONS .....	35
GPB TABLE B.14 INSPECTION/NON-DESTRUCTIVE EXAMINATION (NDE) TECHNIQUES – BENEFITS AND LIMITATIONS .....	37
GPB TABLE B.15 CORROSION MANAGEMENT SYSTEM IMPLEMENTATION BY EQUIP TYPE AND SERVICE .....	41
GPB TABLE C.1 BIOCIDES TREATMENT CONCENTRATION AND INTERVAL .....	55
GPB TABLE C.2 NUMBER OF ER PROBES >2MPY AND ACTIONED .....	57
GPB TABLE C.3 WLC CORROSION RATE DIFFERENCE BY SERVICE AND TYPE .....	61
GPB TABLE D.1 SUMMARY DESCRIPTION OF THE TYPICAL TEST PROGRAM COMPONENTS .....	68
GPB TABLE D.2 FLOW LINE TEST PROGRAM RESULT SUMMARY .....	69
GPB TABLE D.3 SUMMARY OF THE CHEMICAL DEPLOYMENT HISTORY .....	72
GPB TABLE D.4 SUMMARY OF THE CHEMICAL USAGE HISTORY .....	73
GPB TABLE D.5 CORROSION INHIBITOR CONCENTRATION VS. CORROSION RATE .....	77
GPB TABLE E.1 CUI INSPECTIONS BY SERVICE TYPE, 1995-2003 .....	82
GPB TABLE E.2 CUI INCIDENT RATE BY JOINT TYPE .....	83
GPB TABLE E.3 EXTERNAL CORROSION ACTIVITY AND DETECTION SUMMARY .....	84
GPB TABLE E.4 CASED PIPE SURVEY RESULTS .....	86
GPB TABLE E.5 CUMULATIVE CASED PIPE INSPECTION ACTIVITY FROM 1997 TO 2002 .....	88
GPB TABLE E.6 THICKNESS, MAOP CORRELATION .....	95
GPB TABLE E.7 COMPLETED SMART PIG ASSESSMENTS .....	100
GPB TABLE E.8 CASED PIPING EXCAVATION HISTORY .....	103
GPB TABLE F.1 2003 REPAIR ACTIVITY .....	109
GPB TABLE F.2 HISTORICAL REPAIRS BY SERVICE .....	113
GPB TABLE G.1 2003 LEAKS DUE TO CORROSION/EROSION .....	117
GPB TABLE G.2 HISTORICAL CORROSION LEAKS AND SAVES .....	118
GPB TABLE G.3 STRUCTURAL/WALKING SPEED SURVEY SCHEDULE .....	120
GPB TABLE H.1 COUPON PULL FREQUENCY .....	125
GPB TABLE H.2 CORRECTIVE MITIGATION ACTIONS FROM ER PROBE DATA .....	127
GPB TABLE H.3 CORRECTIVE MITIGATION ACTIONS FROM COUPON DATA .....	127
GPB TABLE H.4 CORRECTIVE MITIGATION ACTIONS FROM INSPECTION DATA .....	128

## Table of ACT Tables

ACT TABLE B.1 RELATIVE CORROSIVITY OF BPXA NORTH SLOPE PRODUCTION .....	134
ACT TABLE B.2 ILLUSTRATIVE COMPARISON OF SCALE BETWEEN ACT AND GPB .....	134
ACT TABLE B.3 ENDICOTT SUMMARY OF LINES AND NDE INSPECTIONS .....	135
ACT TABLE B.4 MPU SUMMARY OF LINES AND NDE INSPECTIONS 2003 .....	136
ACT TABLE B.5 NORTHSTAR SUMMARY OF LINES AND NDE INSPECTIONS 2003.....	137
ACT TABLE B.6 BADAMI SUMMARY OF LINES AND NDE INSPECTIONS 2003 .....	137
ACT TABLE B.7 OVERALL INSPECTION ACTIVITY SUMMARY 2000 – 2003 .....	138
ACT TABLE C.1 ENDICOTT CORROSION COUPON MONITORING 2003 .....	139
ACT TABLE C.2 MPU CORROSION COUPON MONITORING 2003.....	140
ACT TABLE C.3 NORTHSTAR CORROSION COUPON MONITORING 2003 .....	141
ACT TABLE D.1 ENDICOTT VELOCITY MONITORING 2001-2003 .....	143
ACT TABLE E.1 CASED PIPING INSPECTIONS .....	146
ACT TABLE E.2 MPU INSPECTION SUMMARY - EXTERNAL.....	147
ACT TABLE E.3 INSPECTION SUMMARY OF MPU S-PAD .....	152
ACT TABLE E.4 INSPECTION SUMMARY OF BADAMI WELL LINES.....	152
ACT TABLE E.5 INSPECTION SUMMARY OF NORTHSTAR .....	153
ACT TABLE F.1 ACT REPAIR ACTIVITY .....	154
ACT TABLE G.1 ENDICOTT LEAK/SAVE AND MECHANICAL REPAIR DATA .....	155
ACT TABLE G.2 MILNE POINT LEAK/SAVE & MECHANICAL REPAIR DATA .....	155
ACT TABLE G.3 NORTHSTAR LEAK/SAVE AND MECHANICAL REPAIR DATA .....	156
ACT TABLE G.4 BADAMI LEAK/SAVE AND MECHANICAL REPAIR DATA .....	156



## **Section A**

### **Charter Agreement – Corrosion Related Commitments**







## **Section A Charter Agreement – Corrosion Related Commitments**

The BPXA contact for all corrosion matters relating to the Charter Agreement is,

Richard C Woollam, Manager CIC Group

E-mail: [woollarc@bp.com](mailto:woollarc@bp.com)

Phone: (907) 564-4437

### **Section A.1 Project Achievements**

Oct-Nov 2000	Work Plan agreed between BPXA/PAI and ADEC (Appendix 1)
March 2001	1 <sup>st</sup> Annual Report submitted to ADEC
April 2001	1 <sup>st</sup> 2001 Meet and Confer session held
Oct-Dec 2001	Consultations with ADEC and ADEC's consultant
November 2001	2 <sup>nd</sup> 2001 Meet and Confer session held
Dec 01-Jan 02	Developed and agreed corrosion management metrics
February 2002	BPXA/PAI and ADEC agreed on performance metrics (Appendix 2)
March 2002	2 <sup>nd</sup> Annual Report submitted to ADEC
April 2002	1 <sup>st</sup> 2002 Meet and Confer session held
November 2002	2 <sup>nd</sup> 2002 Meet and Confer session held
March 2003	3 <sup>rd</sup> Annual Report submitted to ADEC
May 2003	1 <sup>st</sup> 2003 Meet and Confer session held
October 2003	2 <sup>nd</sup> 2003 Meet and Confer session held
March 2004	4 <sup>th</sup> Annual Report submitted to ADEC

### **Section A.2 Annual Charter Timetable**

March 31 <sup>st</sup>	Annual Report submitted
April 30 <sup>th</sup>	1 <sup>st</sup> Semi-Annual Review/Meet and Confer
October 31 <sup>st</sup>	2 <sup>nd</sup> Semi-Annual Review/Meet and Confer



## **Part 1 – Greater Prudhoe Bay Performance Unit**

### **Section B**

#### **Corrosion Monitoring Activities**





## **Section B Corrosion Monitoring Activities**

This section summarizes the Corrosion Management System (CMS) in use at Greater Prudhoe Bay (GPB) Performance Unit, which incorporates Prudhoe Bay, Point McIntyre, Lisburne and Niakuk oilfields plus a number of smaller satellite accumulations all of which are produced through the main separation facilities. A map and brief description of each field and the associated production facilities can be found in Appendix 3. Appendix 4 contains a schematic of a typical production facility configuration.

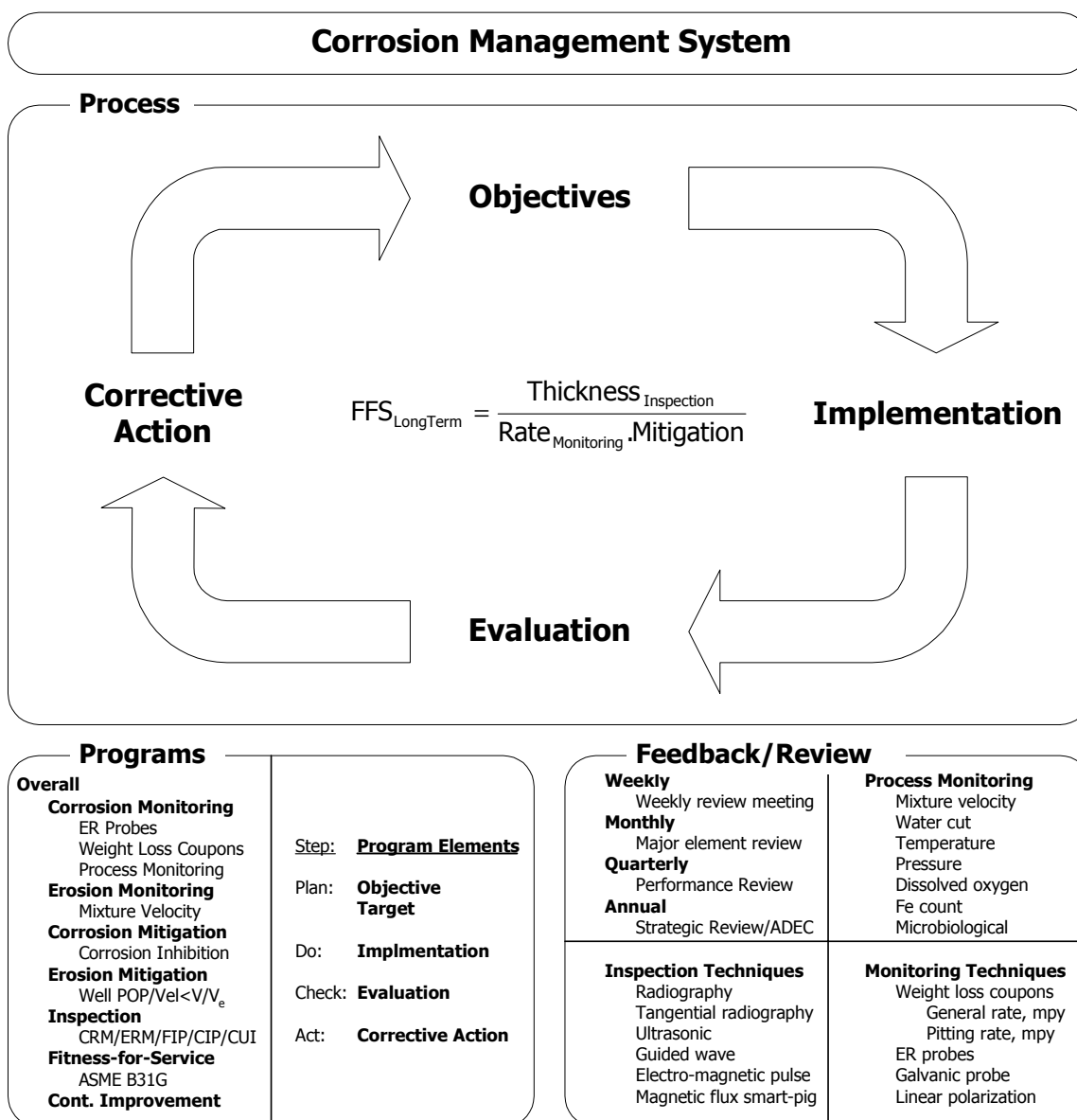
### **Section B.1 Corrosion Management System**

The Corrosion Management System consists of a number of major program elements: Corrosion Monitoring, Erosion Monitoring, Corrosion Mitigation, Inspection and Fitness-For-Service assessment, which follow a simple management process, represented in GPB Figure B.1. The CMS elements are summarized in GPB Table B.9, GPB Table B.10, and GPB Table B.11, at the end of this section. The Corrosion, Inspection and Chemical (CIC) Group utilizes data summarized in the remainder of this report as part of the overall Corrosion Management System.

The overall objective of the CMS is to meet the corporate objectives of 'no accidents, no harm to people and no damage to the environment' which translates for corrosion management within BPXA to delivering a mechanical integrity program which,

- Minimizes health, safety, and environmental impacts of corrosion resulting from a loss of containment
- Provides an infrastructure fit-for-service for the remainder of the life of the oilfield
- Provides infrastructure of sufficient mechanical integrity capable of producing satellite fields/accumulations through existing main production facilities and infrastructure
- Provides an infrastructure to support future major gas production and sales through current North Slope facilities

These overall goals and objectives are achieved through a comprehensive Corrosion Management System that consists of an integrated system of strategy, processes and programs.



**GPB Figure B.1 Overview of the Corrosion Management Process**

### Section B.1.1 Process

Within the overall Corrosion Management System, each specific program element, i.e. Corrosion Monitoring, Mitigation, Inspection and Fitness-For-Service, follows the classic TQM (Total Quality Management) process of 'plan-do-check-act' and consists of,

Step	Activity	Description
Plan	<b>Objective</b>	The program objective and purpose
	<b>Target</b>	The metric against which performance is assessed
Do	<b>Implementation</b>	Implementation plan to achieve objective
Check	<b>Evaluation</b>	Method to evaluate performance of plan against target
Act	<b>Corrective Action</b>	The action required to correct deviation from target

GPB Table B.1 Corrosion Management Process

### Section B.1.2 Objectives and Targets

The objectives<sup>4</sup> for the CMS are set in order to support the delivery of the corporate objective and BPXA objectives described in the introduction to Section B. For the purposes of the CMS these can be translated into the corrosion management objectives of,

- Eliminate corrosion and erosion related failures
- Provide Fit-For-Service infrastructure to the end of field life

Based on these objectives, individual targets are set for the corrosion, erosion, mitigation and inspection programs, which in combination are designed to deliver the objectives. The overall business objectives and individual program objectives and targets are described in detail in GPB Table B.9, GPB Table B.10, and GPB Table B.11.

For example, the weight loss coupons (WLC) in the 3-phase production system have a corrosion rate target of 2 mils per year (mpy). The monitoring program objective is to meet or beat this target, which means an actual WLC corrosion rate of 2 mpy or less ( $WLC \leq 2$  mpy).

### Section B.1.3 Implementation

There are a number of different corrosion monitoring and inspection techniques, each of which has both advantages and disadvantages. The advantages and disadvantages, or strengths and weaknesses, make the results from an individual technique more or less applicable depending on the application circumstances.

GPB Table B.12, GPB Table B.13, and GPB Table B.14 summarize the main categories of corrosion monitoring, process monitoring, inspection techniques and briefly summarize relative strengths and weaknesses for different applications.

---

<sup>4</sup> In addition to Charter Work Plan, some information is supplied to provide additional context and help in understanding BPXA corrosion management activities

#### **Section B.1.4 Evaluation**

The elements of the CMS have to be applied to each system at GPB to reflect their applicability and efficacy. The corrosion and erosion monitoring, inspection and mitigation practices for the major services and equipment type are summarized in GPB Table B.15.

The results from each of the corrosion management programs are reviewed on a regular basis to provide feedback and to take any necessary corrective action based on deviation from target performance. In general, the major review cycles within the CMS are presented in GPB Table B.2.

<b>Review</b>	<b>Description</b>
Weekly	A weekly internal review meeting at which the latest corrosion monitoring, mitigation, inspection and process data are analyzed and reviewed, and any tactical changes implemented
Monthly	Monthly summary of the major elements of the program are reviewed for the need for longer term corrective action
Quarterly	Quarterly strategic performance review held in order to ensure that the implementation plan is delivering the strategic objectives
Annual	Annual program and strategy review designed to review the strategic direction of the program and review effectiveness of the current programs in delivering the strategic direction, e.g. Annual Report to ADEC

**GPB Table B.2 Corrosion Management Feedback Cycles**

Based on the results of the evaluation process, corrective action plans are developed and the overall management program and strategic direction are reviewed.

#### **Section B.1.5 Corrective Action**

Corrective actions provide feedback to the adjustment and setting of Objectives and Targets. Corrective actions can be broken down into five basic categories,

- 1) Chemical Mitigation
- 2) Operational Intervention
- 3) Reduce Maximum Operating Pressure (Derate)
- 4) Repair/Replacement
- 5) Abandon or Remove from Service



Chemical mitigation is discussed in detail in Section D. Operational intervention centers on the GPB Velocity Management Program that is designed to control internal mixture velocity below target values dependent on equipment type, water cut and line size. Repair/replacement programs are driven by the inspection findings and include mechanical sleeves, pipe work refurbishment, and pipeline replacement.

## **Section B.2 Corrosion and Inspection Data Management**

### **Section B.2.1 MIMIR Database**

In order to deliver a comprehensive corrosion management program and manage the extensive corrosion monitoring and inspection activity, it is necessary to have an active and structured electronic database.

Single-operatorship at GPB necessitated the integration of the two aging data systems into a single unified database. This process has been an on-going effort for the last several years. The weight loss coupon, inspection, ER probe and production data are held and accessed through a single database supported by Oracle<sup>®</sup> technology.

Users of the system are provided two primary methods for accessing data stored in the database. The first is a custom user interface written in Microsoft Visual Basic<sup>®</sup>, and the second is through ad-hoc data query tools such as BrioQuery<sup>®</sup> and BusinessObjects<sup>®</sup> which allow free-form SQL<sup>®</sup> access to the data.

Checks for data integrity are provided at a number of different levels including error checking at the point of data capture and data entry, regular reviews of data quality, and data entry rules within the database.

The data are continuously monitored for integrity and quality, and any errors are corrected as they are found. In addition, as better analysis tools become available through further integration then records are amended to reflect the improved level of analysis.

GPB Table B.3 gives an illustration of the number of records and the rate at which those records are accumulated on an annual basis in the database. The table clearly shows the level of complexity and volume of data involved in managing the corrosion programs at GPB.

In addition, the table also shows that the range and types of information being gathered is being improved through time to enable better overall corrosion management at the GPB. The most notable examples of this increasing range of coverage of the corrosion and inspection database is the inclusion of the production and injection data, the introduction of chemical usage data and the long term storage of ER probe data.

<b>Data Record</b>	<b>Unit</b>	<b>Records</b>	<b>#/year</b>	<b>History</b>
Weight loss coupons	10 <sup>6</sup>	0.2	0.01	~20 years
ER probes readings	10 <sup>6</sup>	1.3	0.4	1½ years
Equipment	10 <sup>3</sup>	28	-	-
Inspection locations	10 <sup>6</sup>	0.4	.07	-
Inspection records	10 <sup>6</sup>	1.1	0.1	~12 years
Chemical injection	10 <sup>3</sup>	30	22	1½ years
Production rates	10 <sup>6</sup>	7.8	0.5	~14 years
Injection rates	10 <sup>6</sup>	1.8	0.2	~11 years

**GPB Table B.3 Database Record Accumulation Rate**

## **Section B.2.2 Historical Data**

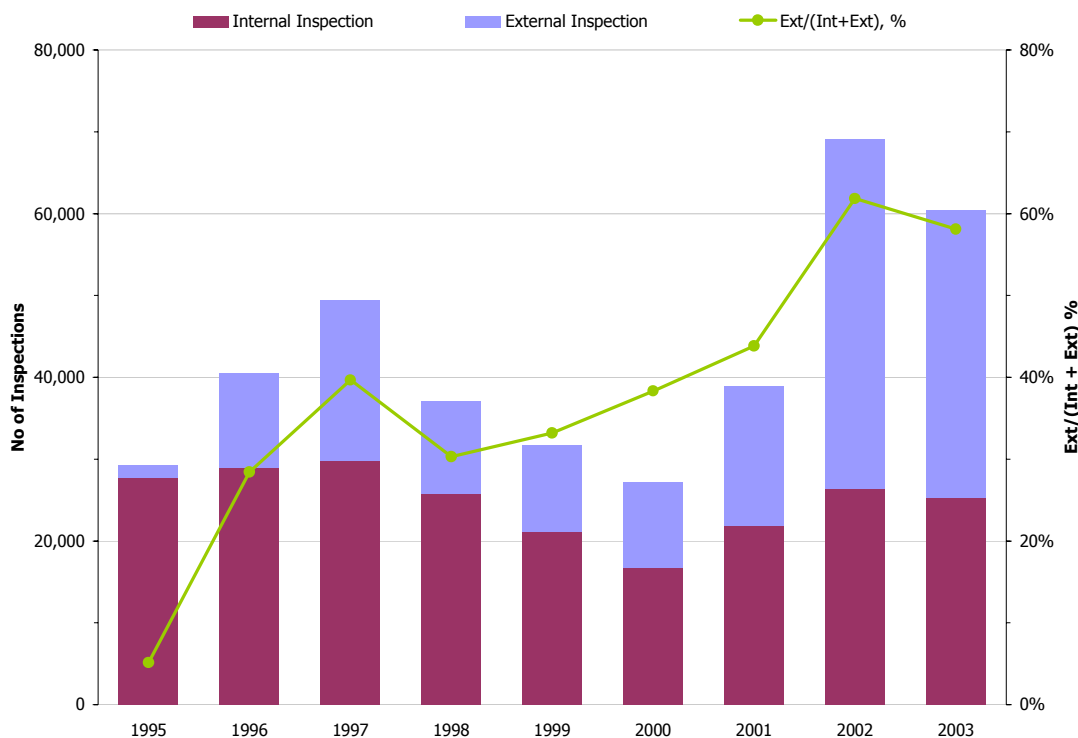
The small differences in data between Annual Reports reflect the movement of lines into and out of service, the addition or abandonment of equipment, and the addition or removal of corrosion access fittings to the program. The historical data for prior years has been updated to reflect the current equipment inventory.

## **Section B.3 Inspection and Corrosion Monitoring Activity Level**

### **Section B.3.1 Inspection Activity**

GPB Figure B.3 summarizes the level of internal and external inspection activity across GPB since 1995 for both cross-country flow lines and well lines. The 2003 internal inspection activity of ~25,000 inspections was consistent with historical levels of activity. From the figure it can be seen that the percentage,  $\frac{\text{Ext}}{(\text{Ext} + \text{Int})}$  %, of the overall inspection effort dedicated to external corrosion inspection in 2003 was consistent with the 2002 forecast of 55%.

GPB Table B.4 illustrates the increased level of external corrosion inspection activity established in 2002 was maintained through 2003. This level is up from the 6-year average (1996 to 2001) of ~13,000 inspections to the 2002/03 target of 35,000 inspections. This is discussed in detail in Section E.1.



**GPB Figure B.2 Internal and External Inspection Activity for Flow and Well Lines**

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003
External	1,508	11,498	19,546	11,235	10,512	10,437	17,037	42,676	35,079
Internal	27,804	28,997	29,860	25,934	21,304	16,861	21,929	26,410	25,382
<b>Total</b>	<b>29,312</b>	<b>40,495</b>	<b>49,406</b>	<b>37,169</b>	<b>31,816</b>	<b>27,298</b>	<b>38,966</b>	<b>69,086</b>	<b>60,461</b>
$\frac{\text{Ext}}{(\text{Ext} + \text{Int})} \%$	5%	28%	40%	30%	33%	38%	44%	62%	58%

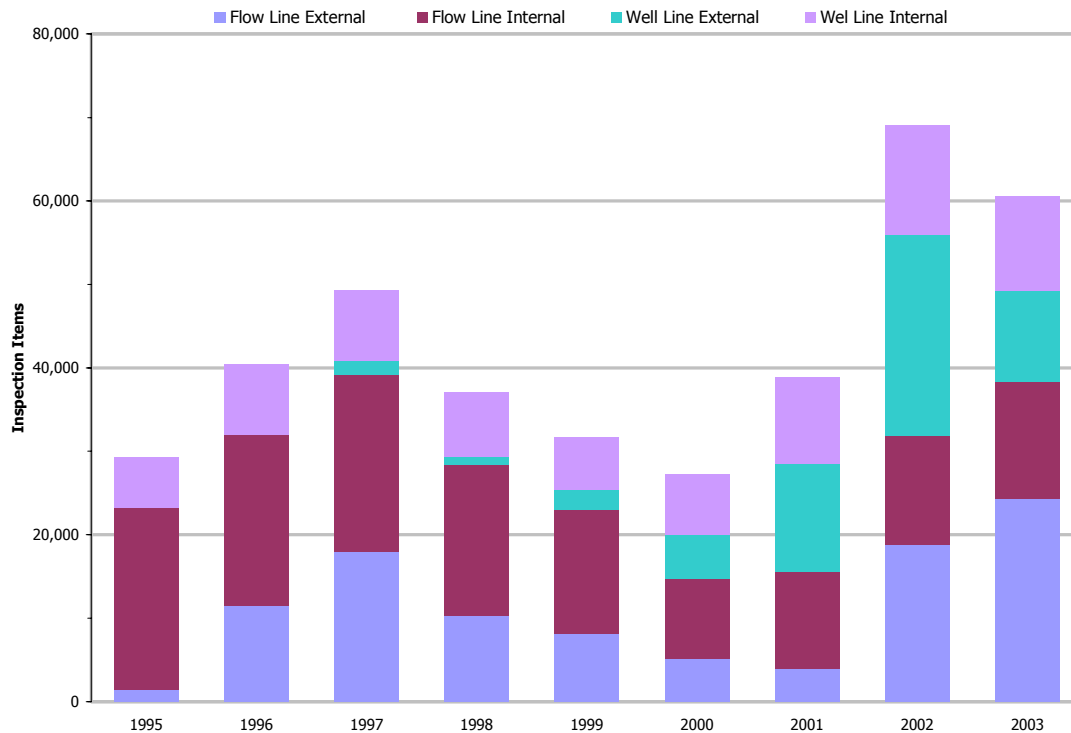
**GPB Table B.4 Internal and External Inspection Activity Breakdown**

GPB Table B.5 and GPB Figure B.3 show the split between flow line and well line inspections for both the internal and external programs. The data show an increase in the number of external flow line inspections and this reflects the difference in focus between 2002 and 2003. The overall inspection activity is running at or above 60,000 inspections per year, in line with the 2002 increased emphasis on external corrosion detection.

Part 1 – Greater Prudhoe Bay Performance Unit

Year		1995	1996	1997	1998	1999	2000	2001	2002	2003
Flow Line	External	1,508	11,462	17,866	10,289	8,136	5,180	3,966	18,727	24,258
	Internal	21,733	20,509	21,329	18,180	14,965	9,612	11,618	13,234	14,131
<b>Total</b>		23,241	31,971	39,195	28,469	23,101	14,792	15,584	31,961	38,389
$\frac{\text{Ext}}{(\text{Ext} + \text{Int})} \%$		6%	36%	46%	36%	35%	35%	25%	59%	63%
Well Line	External	-	36	1,680	946	2,376	5,257	13,071	23,949	10,821
	Internal	6,071	8,488	8,531	7,754	6,339	7,249	10,311	13,176	11,251
<b>Total</b>		6,071	8,524	10,211	8,700	8,715	12,506	23,382	37,125	22,072
$\frac{\text{Ext}}{(\text{Ext} + \text{Int})} \%$		0%	0%	16%	11%	27%	42%	56%	65%	49%
Grand Total		29,312	40,495	49,406	37,169	31,816	27,298	38,966	69,086	60,461
$\frac{\text{FL}}{(\text{FL} + \text{WL})} \%$		79%	79%	79%	77%	73%	54%	40%	46%	63%

**GPB Table B.5 Internal and External Inspection Activity Summary by Flow/Well Line**



**GPB Figure B.3 Internal and External Inspection Activity Summary by Flow/Well Line**

The 2003 in-line inspection (ILI) program consisted of three 24-inch cross-country 3-phase flow lines: S, Y and Pt. McIntyre. Due to the limitations of the magnetic flux leakage (MFL) technique, see GPB Table B.14, the ILI data are used as a guide to the depth and location of damage in the pipeline inspected. This assessment of pipeline condition is then incorporated into the routine ultrasonic and radiographic inspection program. The inspection program verifies the depth of damage, and the location is scheduled for repair and/or re-inspection as necessary.

### Section B.3.2 Corrosion Monitoring Activity

The number of weight loss coupon (WLC) monitoring locations by equipment type and service, is summarized in GPB Table B.6. The relatively small number of differences between years reflects the movement of lines into and out of service, the addition or abandonment of equipment, and the addition or removal of corrosion access fittings to the program.

<b>Service</b>	<b>1995</b>	<b>1996</b>	<b>1997</b>	<b>1998</b>	<b>1999</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>
Flow Line									
3 Phase	220	317	270	276	269	257	260	261	252
Export/PO	3	7	7	5	5	6	4	6	5
Gas	5	5	3	3	3	2	2	2	1
Other	2	2	1	1	1				2
Water	27	28	36	34	37	36	35	38	39
<b>Total</b>	<b>257</b>	<b>359</b>	<b>317</b>	<b>319</b>	<b>315</b>	<b>301</b>	<b>301</b>	<b>307</b>	<b>299</b>
Well Line									
3 Phase	1,057	1,180	1,225	1,210	1,179	1,174	1,089	1,104	1,091
Export/PO		3	6	5	5	5	5	2	2
Gas	6	7	6	6	5	5	6	5	4
Other	1	1	1	1	1	1		3	7
Water	196	206	208	201	186	180	182	185	153
<b>Total</b>	<b>1,260</b>	<b>1,397</b>	<b>1,446</b>	<b>1,423</b>	<b>1,376</b>	<b>1,365</b>	<b>1,282</b>	<b>1,299</b>	<b>1,257</b>
<b>Grand Total</b>	<b>1,517</b>	<b>1,756</b>	<b>1,763</b>	<b>1,742</b>	<b>1,691</b>	<b>1,666</b>	<b>1,583</b>	<b>1,606</b>	<b>1,556</b>

**GPB Table B.6 Corrosion Monitoring Locations by Equipment and Service**

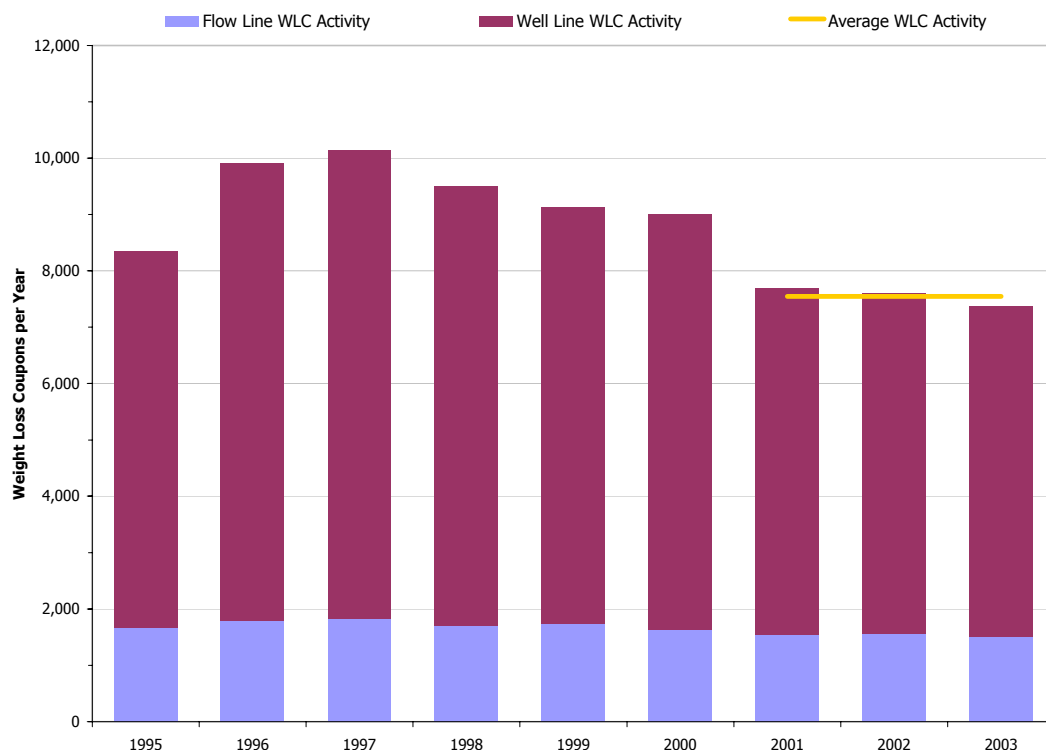
The corrosion-monitoring program is further detailed in GPB Table B.7 and GPB Figure B.4, which shows the number of coupon pulls and number of coupons retrieved, on average, for each active location identified in GPB Table B.6. Two corrosion coupons are typically recovered for each WLC pull with the exception of those lines that are regularly maintenance pigged where single flush mounted coupons are installed. The number of coupons, coupons per pull, and pull frequency has been optimized through time to gain greater value from the data obtained by the program.

As discussed in prior reports, there has been a gradual reduction in the number of weight loss coupons being evaluated, which reflects the on-going effort to optimize the program. Following the rationalization in 2000/01, the level of WLC activity has stabilized at ~7,500 coupons per year (refer to GPB Figure B.4).

<b>Statistic</b>	<b>1995</b>	<b>1996</b>	<b>1997</b>	<b>1998</b>	<b>1999</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>
Flow Line									
# of Equip	196	201	194	192	193	190	187	193	193
Locations	257	359	317	319	315	301	301	307	299
Pulls	926	1,012	1,203	1,110	1,146	1,079	984	1,034	976
FL WLC	1,668	1,788	1,833	1,690	1,738	1,642	1,534	1,551	1,507
WLC/Pull	1.80	1.77	1.52	1.52	1.52	1.52	1.56	1.50	1.54
Pull/Year	3.6	2.8	3.8	3.5	3.6	3.6	3.3	3.4	3.3
Well Line									
# of Equip.	1,128	1,262	1,314	1,325	1,278	1,275	1,193	1,264	1,233
Locations	1,260	1,397	1,446	1,423	1,376	1,365	1,282	1,299	1,257
Pulls	3,373	4,080	4,171	3,922	3,699	3,694	3,099	3,028	2,927
WL WLC	6,684	8,128	8,313	7,806	7,384	7,370	6,152	6,045	5,855
WLC/Pull	1.98	1.99	1.99	1.99	2.00	2.00	1.99	2.00	2.00
Pull/Year	2.7	2.9	2.9	2.8	2.7	2.7	2.4	2.3	2.3
<b>Total Pulls</b>	<b>4,299</b>	<b>5,092</b>	<b>5,374</b>	<b>5,032</b>	<b>4,845</b>	<b>4,773</b>	<b>4,083</b>	<b>4,062</b>	<b>3,903</b>
<b>Total WLCs</b>	<b>8,352</b>	<b>9,916</b>	<b>10,146</b>	<b>9,496</b>	<b>9,122</b>	<b>9,012</b>	<b>7,686</b>	<b>7,596</b>	<b>7,362</b>

**GPB Table B.7 Corrosion Monitoring Activity Statistics by Equipment Type**

The number of weight loss coupons reported for 2003 reflects the inventory of coupons that are installed in the system at year-end that are still to be 'processed.' The reduction in 2003 coupon numbers therefore represents a timing effect and not a reduction in the program scope or activity level.



**GPB Figure B.4 Corrosion Monitoring Activity Statistics by Equipment**

For the electrical resistance (ER) probes, the number of active locations in the flow lines is given in GPB Table B.8. 2003 had the greatest number of ER probes in service which reflects an ongoing effort to utilize ER probe monitoring equipment on all large diameter oil service flow lines.

Year	Total Probe Locations
2001	83
2002	82
2003	85

**GPB Table B.8 Active ER Probe Locations**

Optimization of the corrosion-monitoring program is a continuous effort and any future changes will be reported as part of the Annual Report.

#### **Section B.4 Corrosion Monitoring Activity Summary**

The CMS at GPB provides a framework where individual elements are managed against BPXA's performance targets established by CIC. The overall activity level has remained stable for the last two years at 60,000 inspection locations (35,000 external and 25,000 internal), 85 active ER probe locations, and 7,500 WLC per year.



<b>Program</b>	<b>Plan/Objectives</b>	<b>Target</b>	<b>Implementation</b>	<b>Evaluation</b>	<b>Corrective Action</b>
1.0 Overall program goals	Eliminate corrosion/erosion related failures	No harm to people No accidents No damage to environment Regulatory compliance Compliance with industry standards	Integrated program with monitoring, inspection, operational controls, and corrosion inhibitor	Key performance indicators Leading and lagging indicators	Adjust mitigation, monitoring, and operational targets to meet objective Defect elimination - repair/replace/abandon
	Provide equipment availability to end of Field life	2050	Integrated Program with Monitoring, Inspection, Operational Controls, and Corrosion Inhibition	Key Performance Indicators Leading and Lagging Indicators	Adjust Mitigation, Monitoring, and Operational Targets to Meet Objective
	Cost effective Corrosion Management	Budget	Alliance Partnerships Technical Incentive Contracts Continuous Improvement	Key Performance Indicators Leading and Lagging Indicators	Develop more Cost Effective Methods For Delivering the Program Best in Class Technology Investment for the Future

GPB Table B.9 Corrosion Management System

This page is intentionally blank

<b>Program</b>	<b>Plan/Objectives</b>	<b>Target</b>	<b>Implementation</b>	<b>Evaluation</b>	<b>Corrective Action</b>
1.1 Corrosion Monitoring	Monitor for changes in corrosion rates	System dependant targets Corrosion rate to meet overall objectives Regulatory compliance Compliance with industry standards	Short term corrosion rate determination Medium term corrosion rate determination	ER probes Weight loss coupon rate Pitting Rates	Adjust Mitigating action to achieve corrosion rate target
	Monitor effectiveness of the chemical mitigation programs	Optimize Corrosion Inhibitor Rates and Distribution Optimize chemical mitigation programs e.g. Oxygen scavenger Biocide Drag reducing agent Scale	See above	See above	Provide feedback to Chemical treatment Operations Inspection activities Adjust Mitigation Effort Production Chemistry
	Monitor changes in the process conditions	Field-wide Velocity Management targets	Weekly Review of Operational Controls by CIC Group Operations review of fluid velocities Velocity alarms in Distributive Control System (DCS)	Mixture Velocities, Water Cuts, and Water Rates	Adjust production rates to meet velocity management targets
	Corrosion mechanism changes with time	Mitigation action in place prior to threat to mechanical integrity	Data availability and access Ease of 'data mining' and evaluation Single data storage Comprehensive data management and reporting process	Long-Term Process Change	Develop mitigation program Mechanism management as part of routine business
1.2 Erosion Monitoring	Monitor the effectiveness of the erosion mitigation programs	V/Ve <2.5 Max mixture Velocity and water cut matrix Well Put-On-Production (POP) process Regulatory compliance Compliance with industry standards	Unified velocity management standard across the North Slope Monthly compilation Of High Risk Wells Inspection of High Risk Wells Mixture velocity calculation in DCS	Mixture Velocities Inspection results	Additional inspection and monitoring at high risk sites Adjust Process Conditions Well shut-in Production reduction Design/debottleneck facilities

GPB Table B.10 Corrosion Management System Element – Monitoring

This page is intentionally blank

<b>Program</b>	<b>Plan/Objectives</b>	<b>Target</b>	<b>Implementation</b>	<b>Evaluation</b>	<b>Corrective Action</b>
1.3 Corrosion Mitigation	Mitigate Corrosion Through Application of Corrosion Inhibitors	Control Corrosion Rates to Acceptable Levels (See Overall Program Goals) Regulatory compliance Compliance with industry standards	Continuous Injection into individual wells as far upstream as possible - currently at Wellhead Protect all equipment between injection point and separation plant	ER Probes WLC's Inspection	Corrosion Inhibitor Development Adjust Mitigation Effort
		Control Corrosion Rates to Acceptable Levels (See Overall Program Goals)	Batch Treatments on a routine schedule with injection at the Wellhead	WLC's Inspection	Corrosion Inhibitor Development Adjust Mitigation Effort Through Reviews
	Mitigate Corrosion through Operational Controls	Operational Guidelines	Weekly Reviews by CIC Group	Mixture Velocities	Adjust Process Conditions
	Mitigate Corrosion through Maintenance Pigging	Achieve Scheduled Frequency	Maintenance Pigging	Inspection Pigging Returns	Adjust Maintenance Pigging Schedule
1.4 Erosion Mitigation	Mitigate Erosion Through Operational Controls and Design	Control Erosion Rates to Acceptable Levels (See Overall Program Goals) V/Ve < 2.5 Regulatory compliance Compliance with industry standards	Well POP process V/Ve Guidelines	V/Ve Inspection (ERM)	Adjust Process Conditions

GPB Table B.10 (continued) Corrosion Management System Element – Mitigation

This page is intentionally blank

<b>Program</b>	<b>Plan/Objectives</b>	<b>Target</b>	<b>Implementation</b>	<b>Evaluation</b>	<b>Corrective Action</b>
1.5 Inspection	Integrated inspection program to provide a overall assessment of plant condition and corrosion rates	Inspection activity level Leak/save target Inspection increases Plant condition Regulatory compliance	Corrosion rate monitoring program (CRM) Erosion rate monitoring program (ERM) Comprehensive inspection program (CIP) Frequent inspection program (FIP) Corrosion under insulation program (CUI)	NDE technique sheets and procedures Standardized assessment of piping condition, degradation rate and mechanism	Provide feedback to chemical mitigation program Erosion management program Fitness for service assessment Equipment life assessment Proactive repair scheduling
	Assessment of Current Damage Mechanisms	Zero Increases	Internal and external programs	See above	Repair/replace/monitor
	Search for New Damage Mechanisms	Mitigation action in place prior to threat to FFS	Baseline new equipment Apply lessons learnt from industry practice else where in the world Apply lessons learned for other BP operations Apply learnings across the field for similar equipment/process conditions Communications with Operations and Reservoir Engineers	See above	Develop mitigation program Mechanism management as part of routine business
1.6 Fitness for Service	Fitness for service assurance	Regulatory compliance Compliance with industry standard	See above inspection programs	Battelle Modified B31G fitness-for-service criteria (note piping only) BP internal specification for the assessment of damaged pipe	Repair equipment Replace equipment Derate equipment Abandon equipment
	Structural integrity	Regulatory compliance Compliance with industry standard	Walking speed survey every 5 years	Piping design code BP Spec, B31.4 and B31.8 Piping stress analysis Nondestructive testing as required	Repair/replace Correct support defect Monitor for further degradation

GPB Table B.10 (continued) Corrosion Management System Element – Inspection

This page is intentionally blank



<b>Program</b>	<b>Plan/Objectives</b>	<b>Target</b>	<b>Implementation</b>	<b>Evaluation</b>	<b>Corrective Action</b>
1.7 Continuous Improvement	Provide Feedback to Monitoring, Mitigation, and Inspection Programs	Continuous Improvement	Integrated Program with Monitoring, Inspection, Operational Controls, and Corrosion Inhibitor Provides Feedback Control Loop for Program Improvements Consolidated data store, MIMIR	Weekly program review Quarterly program review Annual program reviews and strategy assessment Annual equipment life/availability review Key Performance Indicators	Strategic adjustment Budget/funding level changes Mitigation process change and review Technical/R&D requirements and programs

GPB Table B.10 (continued) Corrosion Management System Element – Inspection

This page is intentionally blank

<b>Program</b>	<b>Plan/Objectives</b>	<b>Target</b>	<b>Implementation</b>	<b>Evaluation</b>	<b>Corrective Action</b>
1.1.1 Monitoring – Electrical Resistance Probes (ER)	Monitor the Effectiveness of the Mitigation Programs	< 2mpy Regulatory compliance Compliance with industry standard	ER Probes - Upstream and/or Downstream Ends of Flow lines	Investigate Cause for Corrosion Rate Increase	Mitigation Adjustments ER Probe Maintenance
1.1.2 Monitoring – Weight Loss Coupons (WLC)	Monitor the Effectiveness of the Mitigation Programs	Gen CR: < 2mpy Pit CR: < 20mpy Regulatory compliance Compliance with industry standard	WLC – Installed Flow lines, Well lines, Headers, and Piping	Investigate Cause for Corrosion Rate Increase	Mitigation Adjustments Inspection Program Adjustments
1.1.3 Monitoring – Process Conditions	Monitor changes in the Process Conditions	(See Mixture Velocity and Erosion Sections Below) Regulatory compliance Compliance with industry standard		Investigate Cause for Process Upset Long-Term Process Change Monitor Impact	Mitigation Adjustments
1.1.4 Monitoring – Mixture Velocity Management Program	Monitor the Effectiveness of the Mitigation Programs	Operational Guidelines Mix Vel Limits Regulatory compliance Compliance with industry standard	Operations Acceptance of Mixture Velocity Guidelines SETCIM	Review Alarm List to Determine True Offenders	Adjust Process Conditions
1.1.5 Monitoring – Erosion Management Program	Monitor the Effectiveness of the Erosion Mitigation Programs	Operational Guidelines Well Put on Production (POP) $V/V_e < 2.5$ Regulatory compliance Compliance with industry standard	Operations Acceptance of Erosion Guidelines High Risk Well Inspection Program (ERM)	Monthly Reviews to Determine High Risk Equipment and Repeat Offenders	Adjust Process Conditions

**GPB Table B.11 Monitoring Program Techniques**

This page is intentionally blank

<b>Program</b>	<b>Plan/Objectives</b>	<b>Target</b>	<b>Implementation</b>	<b>Evaluation</b>	<b>Corrective Action</b>
1.2.1 Mitigation – Corrosion Inhibitor	Mitigate Corrosion Through Application of Corrosion Inhibitors	Control Corrosion Rates to Acceptable Levels (See Overall Program Goals) Regulatory compliance Compliance with industry standard Control Corrosion Rates to Acceptable Levels (See Overall Program Goals)	Continuous Injection Into Individual Wells as Far Upstream As Possible – Currently at Wellhead Protect All Equipment Between Injection Point and Separation Plant  Batch Treatments on a Routine Schedule with Injection at the Wellhead	ER Probes WLC's Inspection  WLC's Inspection	Corrosion Inhibitor Development Adjust Mitigation Effort  Corrosion Inhibitor Development Adjust Mitigation Effort through Reviews
1.2.2 Mitigation – Operational Control, Maintenance, and Material Selection	Mitigate Corrosion Through Operational Controls  Mitigate Erosion through Operational Controls  Mitigate Corrosion through Maintenance Pigging Corrosion Resistant Alloys	Operational Guidelines Mixture Velocity Limits Regulatory compliance Compliance with industry standard Operational Guidelines Well POP $V/V_e < 2.5$  Achieve Scheduled Frequency Zero Increases (I's)	Operations Acceptance of Mixture Velocity Guidelines  Operations Acceptance of Erosion Guidelines High Risk Well Inspection Program (ERM) Maintenance Pigging  Selected Facilities & Equipment	Mixture Velocities Review Alarm List to determine true offenders  Monthly Reviews to Determine High Risk Equipment and Repeat Offenders Inspection Pigging Returns Inspection Applicability For Service Requirements	Adjust Process Conditions  Adjust Process Conditions  Adjust Maintenance Pigging Schedule Replace as Necessary
1.2.3 Mitigation – Structural Integrity	Mitigate structural damage caused by subsidence, jacking, vibration, impact, snow loading, etc. through inspections	No failures due to structural damage Regulatory compliance Compliance with industry standard	Operational procedures for visual surveillance of pipelines Piping stress analysis as required NDE inspections as required	Review Pipeline Design Code/BP Specification	Repair, replace and correct deficiencies as required Add Pipeline Vibration Dampeners (PVDs) as required

GPB Table B.11 (continued) Mitigation Program Techniques

This page is intentionally blank

<b>Program</b>	<b>Plan/Objectives</b>	<b>Target</b>	<b>Implementation</b>	<b>Evaluation</b>	<b>Corrective Action</b>
1.3.1 Corrosion Rate Monitoring (CRM)	Assessment of current corrosion mechanisms Monitor for new corrosion mechanisms	No measurable active corrosion -Zero increases (I's) Regulatory compliance Compliance with industry standard	CRM Program – Fixed locations on approximately bi-annual frequency	Inspections Condition of Equipment Rate of degradation	Mitigation Adjustments Repair/Replace Preventative Maintenance
1.3.2 Erosion Rate Monitoring (ERM)	Monitor high risk wells Assessment of current erosion locations	Manageable rate of degradation Regulatory compliance Compliance with industry standard	ERM Program – monthly to quarterly	Inspections Condition of Equipment Rate of degradation	Mitigation Adjustments Repair/Replace Preventative Maintenance
1.3.3 Frequent Inspection Program (FIP)	Assessment of High Corrosion Rates Monitor locations near repair	Fitness-for-Service Regulatory compliance Compliance with industry standard	FIP Program – monthly to bi-annual	Inspections Condition of Equipment Rate of degradation	Mitigation Adjustments Repair/Replace Preventative Maintenance
1.3.4 Comprehensive Integrity Program (CIP)	Comprehensive Coverage of equipment Fitness-for-Service review	Fitness-for-Service Regulatory compliance Compliance with industry standard	CIP – Condition and rate based half-life recurring frequency Extend coverage through new locations	Inspections Condition of Equipment Rate of degradation	Mitigation Adjustments Repair/Replace Preventative Maintenance
1.3.5 Corrosion Under Insulation (CUI)	Comprehensive Coverage of equipment	Inspection of Locations susceptible to CUI Fitness For Service Regulatory compliance Compliance with industry standard	CUI – Risk based annual program Management of location inventory through recurring examinations	Detect Damage Areas Analysis of occurrence	Repair/Replace Preventative Maintenance

**GPB Table B.11 (continued) Mitigation Program Techniques**

This page is intentionally blank



Method	Technique	Description	Sensitivity	Accuracy	Freq	Notes/Comments
Corrosion Monitoring	Electrical Resistance (ER) Probes	Measurement of corrosion rate by monitoring changes in electrical resistance of a metal probe due to volume loss	High	Low	H/D	Correlate poorly to actual pipewall corrosion rates
	Weight Loss Coupons Corrosion Rate	Exposure of metal samples to corrosive fluid and calculation of volume loss rates based on weight	Medium	Medium	M	Limited benefit in determining short-term effects, such as flow regime changes on corrosion rates
	Weight Loss Coupons Pitting Rate	Exposure of metal samples and assessment of pitting rate via measurement of pit depths	Medium	Medium	M	Not a very sensitive measure for GPB 3phase but more effective in the PW system
	Galvanic Probe	Detects changes in corrosivity as a function of current flow between two dissimilar metals.	High	Low	C	Not a reliable measurement of mild steel corrosion rate. Very suitable to monitor oxygen and chlorine changes in seawater
	Linear Polarization Resistance (LPR)	Electrochemical technique for assessing corrosion rate by application of controlled voltage and measuring current response	High	Low	H/D	Not used at GPB due to the interference of hydrocarbon films on measurement

GPB Table B.12 Corrosion Monitoring Techniques – Benefits and Limitations

Method	Technique	Description	Sensitivity	Accuracy	Freq	Notes/Comments
Process Monitoring	Mixture velocity	Mixture velocity of fluids in pipe-work	Medium	Medium	D	Accuracy dependent upon production information (T, P, Oil, Water, Gas)
	Water cut	Percent water in liquid fluids	Medium	Medium	D	Accuracy dependent upon production information (Oil, Water)
	Temperature and pressure	Measured temperature and pressure in process equipment	Medium	Medium	D	
	Dissolved Oxygen	Amount of oxygen dissolved in Sea Water	High	Medium	D	In-line accuracy problematic. Chemet method more accurate
	Iron (Fe) counts	Amount of Iron (Fe) dissolved in process water	High	Low	M	
	Microbiological activity	Amount of microbiological life forms in process fluids	Medium	Low	M	

GPB Table B.13 Process Monitoring techniques – Benefits and Limitations

This page is intentionally blank

Method	Technique	Description	Sensitivity	Accuracy	Freq	Notes/Comments
Inspection/NDE	Radiographic Testing (RT)	Assessment of pipe wall degradation by passing gamma or x-ray radiation through a specimen and projecting an image on conventional lead screen/film. Irregular density variations of the image can indicate metal loss.	Medium	Medium	M/Q/H/ Y	Utilized for detection, monitoring, and fit for service assessment of pipe metal loss in the form of mechanical, corrosion, and erosion degradation. Currently being phased out in lieu of 'greener' process of DRT – see below
	Digital Radiographic Testing (DRT)	Assessment of pipe wall degradation by passing gamma or x-ray radiation through a specimen and projecting an image on phosphor screen/imaging plate. Irregular density variations of the image can indicate metal loss.	Medium	Medium	M/Q/H/ Y	Utilized for detection, monitoring, and fit for service assessment of pipe metal loss in the form of mechanical, corrosion, and erosion degradation. DRT provides additional benefits in waste reduction associated with conventional film and processing chemicals
	Tangential Radiography Testing (TRT)	Assessment of pipe wall degradation by passing gamma or x-ray radiation through insulation at the tangent of the specimen and projecting an image on screen/film, phosphor screen/imaging plate, or detector array.	High	Low	Y	Utilized for detection of corrosion under insulation (CUI). Deployed where potential moisture ingress is suspected on thermally insulated piping
	Ultrasonic Testing (UT)	Assessment of pipe wall thickness by sending/receiving ultrasound through a specimen. Echoes returning indicate remaining thickness of the specimen.	Medium	High	M/Q/H/ Y	Utilized for detection, monitoring, and fit for service assessment of pipe metal loss in the form of mechanical, corrosion, and erosion degradation
	Guided Wave Ultrasonic Testing (GUT)	Volumetric assessment of pipe wall by sending/receiving ultrasound through a specimen in the form of cylinder Lamb Waves. Monitoring changes in these waves indicate potential changes in pipe thickness. Alternatively, echoes returning to the source transducer may also indicate interruptions or pitting in the pipe segment.	Low	Low	Y	Utilized for cased piping assessment where access does not support use of traditional inspection methods. The method is capable of semi-quantifying metal loss but cannot discriminate between internal and external corrosion
	Electromagnetic Pulse Testing (EMT)	Assessment of pipe wall by propagating broadband electromagnetic waves on the exterior surface of the specimen. When waves traveling down steel pipe encounter corrosion on the pipe surface, the waves are distorted. Distortions in waveform may indicate rust by-product on the surface of the steel and subsequent metal loss.	High	Low	Y	Utilized for cased piping assessment where access does not support use of traditional inspection methods. The method cannot quantify metal loss and has a tendency to report false positive results but seldom overlooks surface atmospheric corrosion

GPB Table B.14 Inspection/Non-Destructive Examination (NDE) Techniques – Benefits and Limitations

This page is intentionally blank

Method	Technique	Description	Sensitivity	Accuracy	Freq	Notes/Comments
Inspection/NDE (Cont)	In-line Inspection – Smart Pig Magnetic Flux (MFL) Technique	Assessment of pipelines for the detection and measurement of metal loss. These pigs carry high strength magnets, which apply a strong magnetic field into the pipe wall. The magnetic field saturates the pipe steel with magnetic flux. As a result, areas of metal loss cause the flux to leak out of the pipe wall. The flux leakage data are recorded and used to infer the size and depth of any metal loss defects in the pipe.	High	Medium	N/A	Utilized where design and process operation permit in-line pigging. Metal loss MFL In-line Inspection provides complete evaluation of pipeline integrity within the limitations of the MFL technique.

GPB Table B.14 (continued) Inspection/Non-Destructive Examination (NDE) Techniques – Benefits and Limitations

This page is intentionally blank

Service	Equipment Type	Monitoring Technique	Inspection Program	Mitigation Program*
Oil	Flow line	ER Probes WLC Process Monitoring	CRM FIP CIP CUI	CI Injection Mixture Velocities Periodic Maintenance Pigging Operational Controls
	Well line	WLC Process Monitoring	CRM ERM FIP CIP CUI	CI Injection Mixture Velocities Mixture Velocities Operational Controls
Produced Water	Flow line	WLC	CRM FIP CIP CUI	CI Injection** CI Carry Over Periodic Maintenance Pigging Mixture Velocities Operational Controls
	Well line	WLC	CRM FIP CIP CUI	CI Injection** CI Carry Over Mixture Velocities Operational Controls
Seawater	Flow line	WLC Galvanic Probes Dissolved O <sub>2</sub> Microbiological Activity	CRM FIP CIP CUI	Biocide Treatment O <sub>2</sub> Scavenger Periodic Maintenance Pigging Operational Controls
	Well line	WLC Microbiological Activity	CRM FIP CIP CUI	Biocide Treatment Periodic Maintenance Pigging Operational Controls
Export oil	Flow line	WLC ER Probes	CRM FIP CIP CUI	CI Carry Over Mixture Velocities Operational Controls Periodic Maintenance Pigging

\*Applicable to all inspection programs noted

\*\*No CI injection for FS-2 PW

**GPB Table B.15 Corrosion Management System Implementation by Equip Type and Service**

This page is intentionally blank



## **Section C**

### **Weight Loss Coupons and Probes**





## **Section C Weight Loss Coupons and ER Probes**

This section summarizes the results of the weight loss coupon corrosion monitoring and ER probe programs. Each of the major service categories are reviewed in turn with the results of the program discussed along with major conclusions and significant recommendations.

Detailed data tables for each configuration of equipment type, flow line and well line, and each service category, 3-phase, produced water and seawater, are provided in Appendix 5.

### **Section C.1 Three Phase Production Systems**

The corrosion mechanism of concern in the 3-phase production system is CO<sub>2</sub> corrosion, in which CO<sub>2</sub> from the produced fluids dissolves and dissociates in the produced water to form an acidic environment that is, if untreated, corrosive to carbon steel<sup>5,6</sup>. The primary corrosion control method is the continuous addition of corrosion inhibitor in the flow lines and a mix of continuous and batch inhibitor additions in the well lines.

For the 3-phase production system the target corrosion rate from weight loss coupons is a general corrosion rate of 2 mpy or less (WLC ≤2 mpy).

#### **Section C.1.1 Cross Country Flow Line Coupons**

GPB Figure C.1 shows the average corrosion rate and percentage of coupons meeting the performance standard target since 1992. The results show the percentage of conformant flow lines has improved consistently over the last decade. The average corrosion rate for 2003 across GPB is approximately a factor of 10 lower than the corrosion rates from the early 1990's.

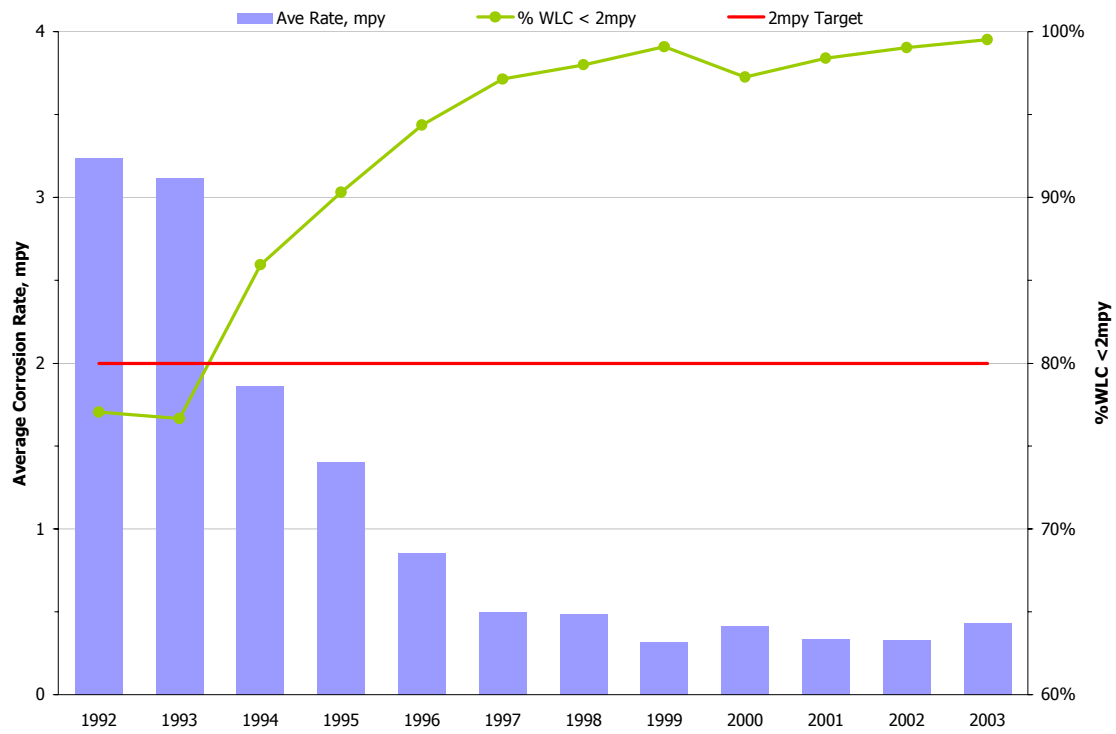
The reduction in corrosion rate is a direct result of the implementation of an aggressive corrosion mitigation program consisting primarily of continuous addition of corrosion inhibitor into the production fluids. The results from 2003 demonstrate the most effective level of corrosion management that has been achieved. This mitigation program has been implemented at considerable capital and operating expense but has resulted in flow lines which are now expected to be fit-for-service (FFS) for approximately 10 times as long as that expected in the early 1990's due to the reduction in corrosion rate.

---

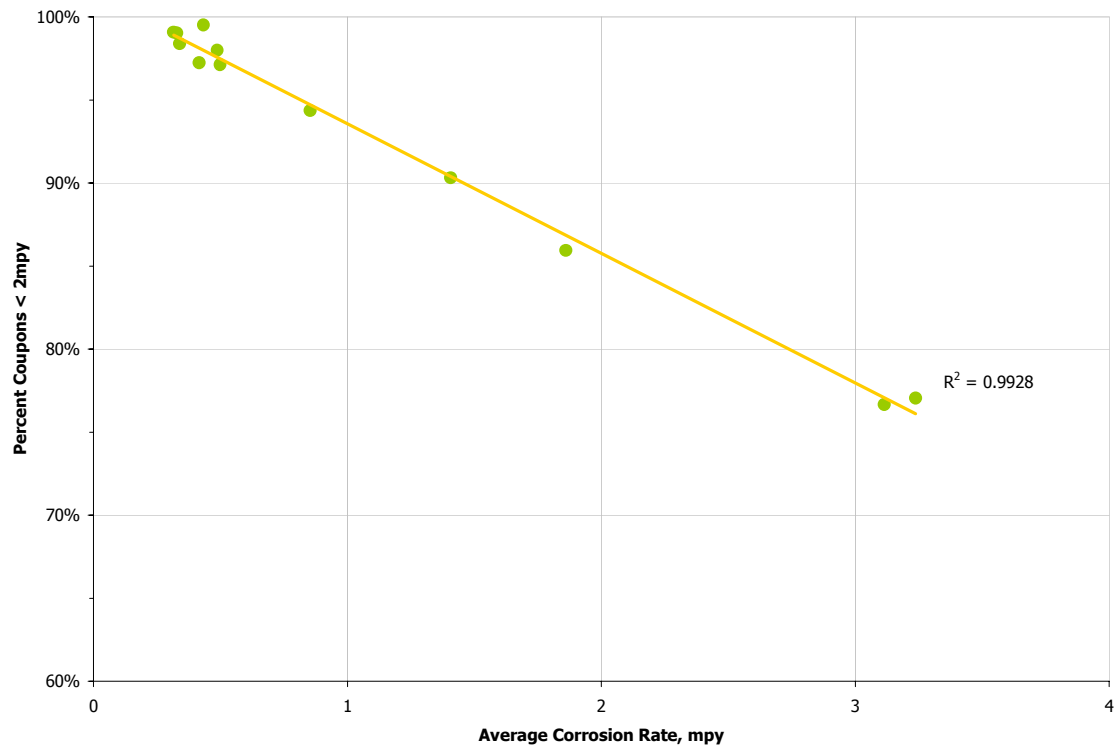
<sup>5</sup> Corrosion Control in Petroleum Production, Harry G Byers, NACE, 1999

<sup>6</sup> Corrosion Control in Oil and Gas Production, Treseder and Tuttle, NACE, 1998

## Part 1 – Greater Prudhoe Bay Performance Unit



**GPB Figure C.1 Flow Line Oil Service Corrosion Rate Trend**



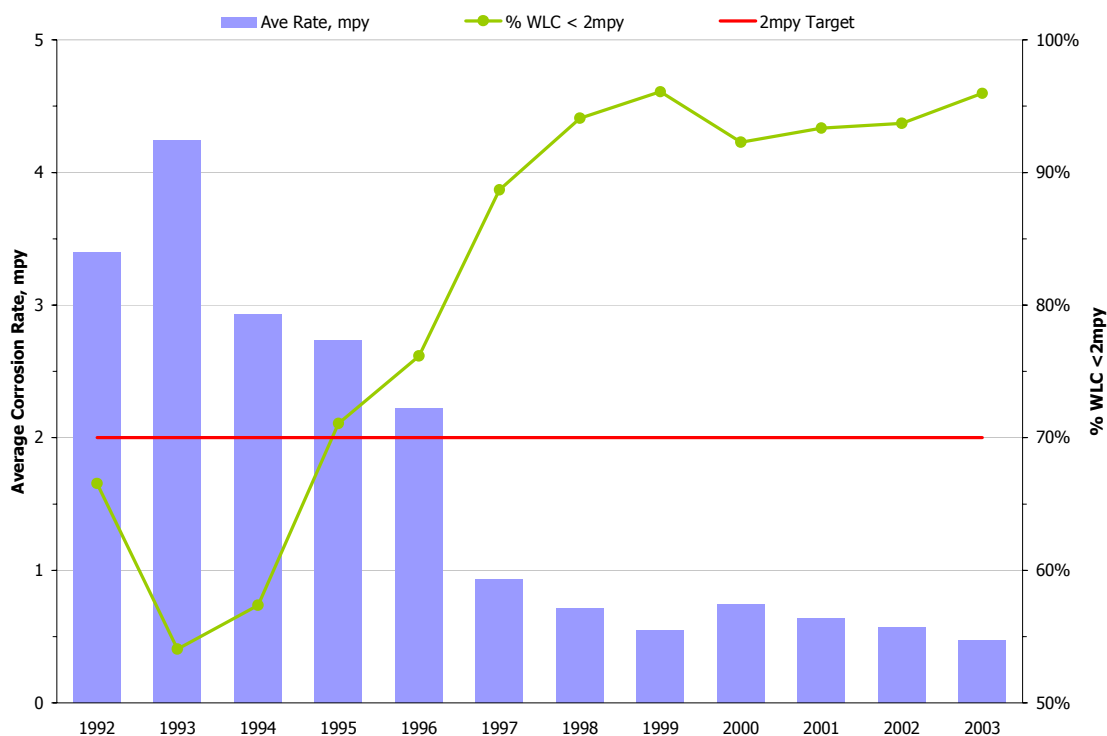
**GPB Figure C.2 Correlation Between Flow Line Corrosion Rate and Percentage Conformance**

GPB Figure C.2 shows the correlation between average corrosion rate and the percentage of weight loss coupons meeting the 2 mpy target. As might be expected, there is a very strong correlation between these two metrics. However these two metrics should be viewed as being complementary. The percentage less than 2 mpy target has the advantage of highlighting non-conformances that would otherwise be lost in the calculation of the average.

Conversely, the average corrosion rate has the advantage of showing the overall performance trend that would otherwise be lost when only looking at the exceptions >2 mpy. Hence, it is necessary to review both metrics in order to gain an overall understanding of the performance of the program.

### Section C.1.2 Well Line Coupons

GPB Figure C.3 shows the average corrosion rate and percentage of WLC  $\leq 2$  mpy since 1992. The trends are very similar to those seen in the cross-country oil flow lines, showing a long-term improvement in the level of control from early 1990's to the present day. The corrosion rate is at its lowest value and the percentage of coupons  $\leq 2$  mpy is at the highest value since 1992.



**GPB Figure C.3 Well Line Oil Service Corrosion Rate Trend**

The long term corrosion control improvement in the well lines is of the same magnitude as that seen in the flow lines with corrosion rates being reduced from an average >4 mpy in 1993 down to an average of 0.5 mpy for 2003.

### Section C.1.3 Three Phase Coupon Program Summary

The 3-phase production system has seen a consistently strong improvement in corrosion control since the early 1990's with a near order of magnitude reduction in the cross-country flow line corrosion rates. A similar trend is also seen in the inspection history discussed later in Section E. The decrease in corrosion rates in the 3-phase systems is attributable to the implementation and continuation of the aggressive corrosion inhibition program. The correlation between corrosion inhibitor concentration and corrosion rates in 3-phase flow lines is discussed in detail in Section D.

### Section C.2 Water Injection Systems

The Water Injection System at GPB is comprised of produced water from the primary processing/separation facilities and seawater extracted from the Beaufort Sea and processed through the Seawater Treatment Plant (STP).

As noted in the 2002 Report, the production database has now been linked to the corrosion and inspection database. This dynamic link provides a much more detailed view of service history/changes for the well line equipment, enabling an improved level of data analysis and quality.

As a consequence of the dynamic linking of the weight loss coupon history to the injection and production data, the totals in Section C will not match the activity totals in Section B, which are reported independent of the injection or production service.

The new reporting format, which augments the performance metrics and was agreed with ADEC, can be summarized as follows:

<b>Report Date</b>	Mid point of the WLC's exposure period, $\text{Mid Date} = \text{Date In} + \frac{(\text{Date Out} - \text{Date In})}{2}$
<b>Service Type</b>	(a) Average corrosion rate with 100% exposure to service (b) Average corrosion rate with simple service majority

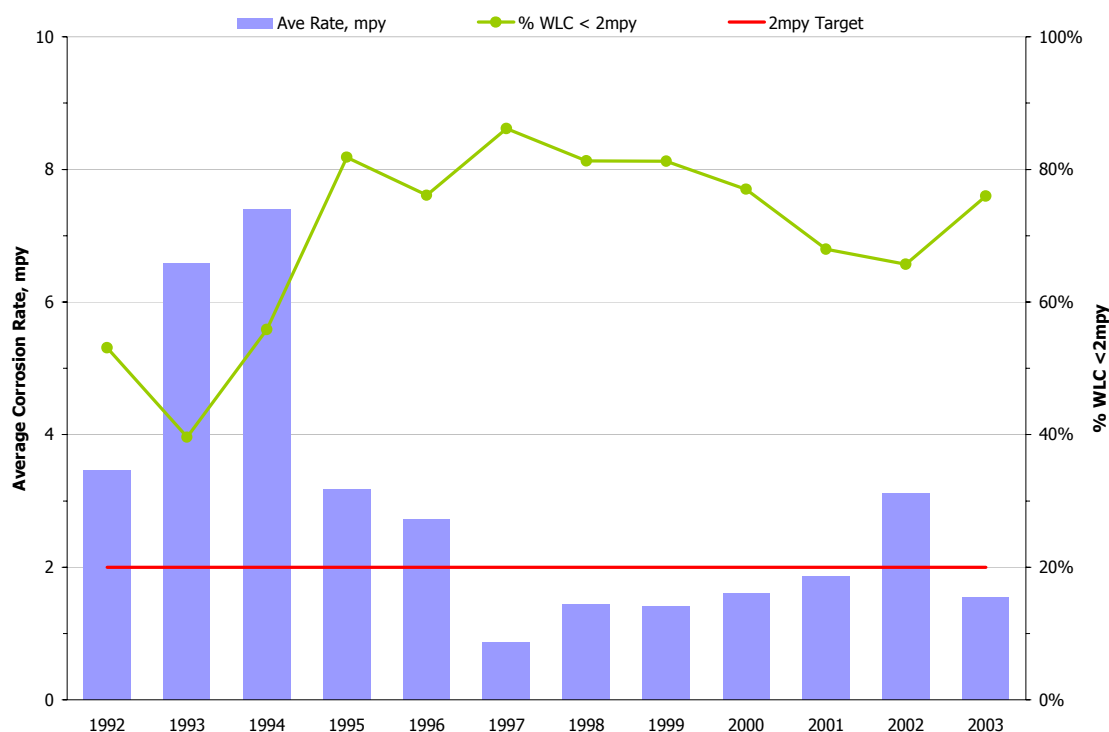
Full data sets are included in the data tables in Appendix 5.

#### Section C.2.1 Water Injection System Flow Lines

GPB Figure C.4 is a summary of aggregate data for produced water and seawater flow lines. The data show the 2003 WLC corrosion rates have decreased below the 2 mpy target. The decrease in rate is largely due to corrosion mitigation actions taken in the SW system, which are discussed in detail in Section C.2.3.

The data set for 2003 has been expanded from previous years. Additional monitoring locations, from the facility piping, have been added to the data set to provide increased insight into the performance of the water injection flow lines.

These locations are exposed to mainline flow but are physically located inside the facility module walls.



**GPB Figure C.4 Flow Line PW/SW Service Corrosion Rate Trend**

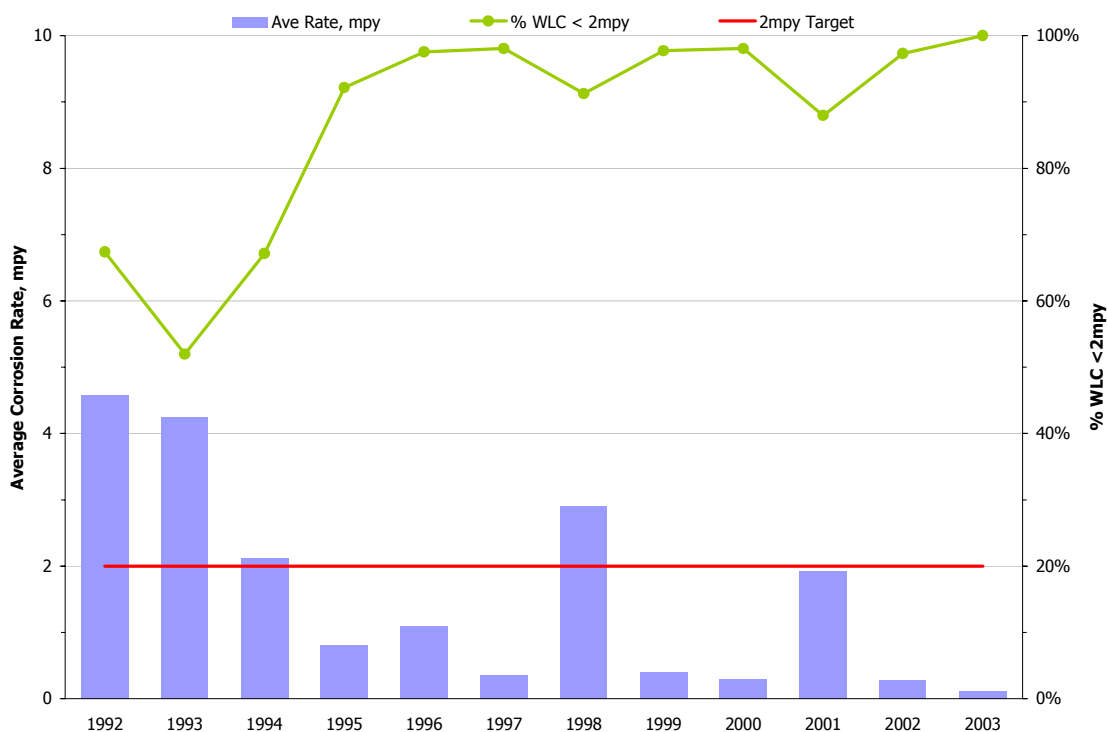
In summary, the average WLC corrosion rates for the aggregate water injection service improved in 2003, reversing a negative 5-year trend. This improvement is attributable to corrosion mitigation actions in the seawater system over the recent years.

### **Section C.2.2 Produced Water Injection Well Lines**

There are a number of corrosion mechanisms of concern in the produced water (PW) injection system. These mechanisms include CO<sub>2</sub> corrosion and differential concentration effects due to the high particulate content of the system. The particulates consist primarily of residual hydrocarbon remaining after the separation process, entrained production chemicals, and iron sulfides.

GPB Figure C.5 through GPB Figure C.7 summarize the historical corrosion rate data for produced water well lines. The data show the general corrosion rates in the produced water system have fallen as the level of inhibition in the 3-phase system was increased and supplemental produced water corrosion inhibitor injection was initiated.

## Part 1 – Greater Prudhoe Bay Performance Unit



**GPB Figure C.5 Corrosion Rates for 100% PW System**

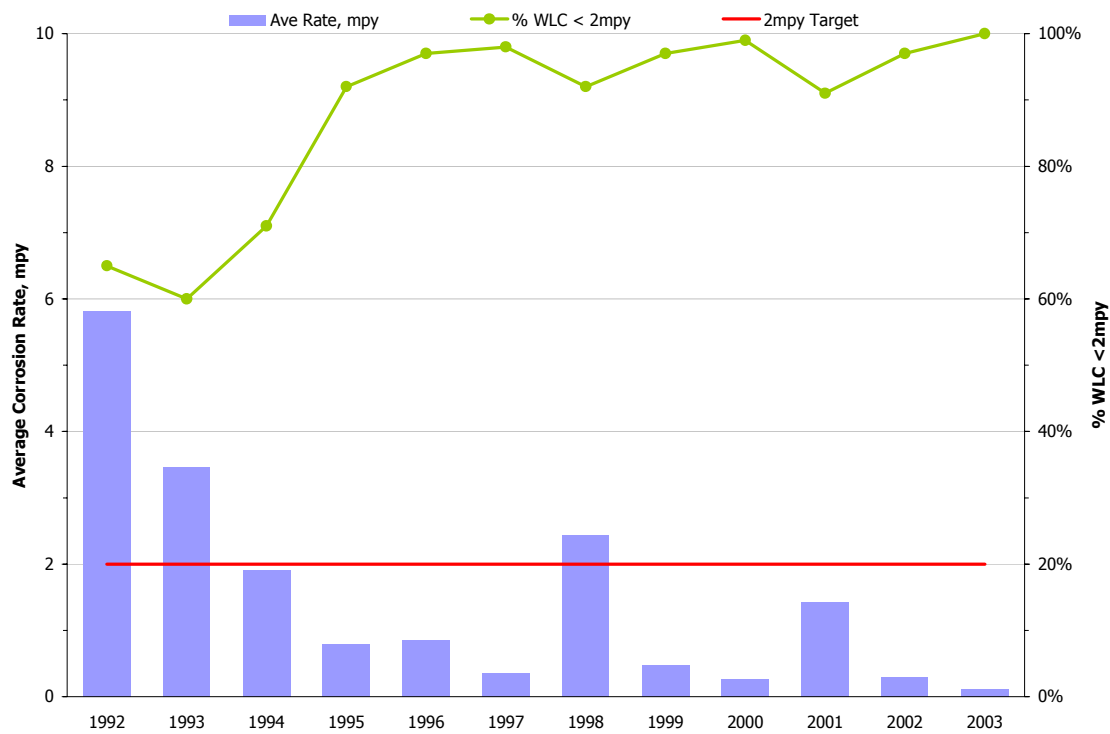
GPB Figure C.5 shows the performance for 100% produced water service. The 2003 levels reached a system best with average corrosion rates at ~0.1 mpy and 100% WLC  $\leq$  2 mpy. This initial evaluation of the new treatment is encouraging, but caution is warranted as the data set is limited and long-term trend has not been established.

For those coupons where produced water was the majority service, GPB Figure C.6 shows the corrosion rate trends were very similar to those seen for 100% produced water service. Again, the results for 2003 are encouraging, but caution is warranted as the data set is limited, and long-term trend has not been established.

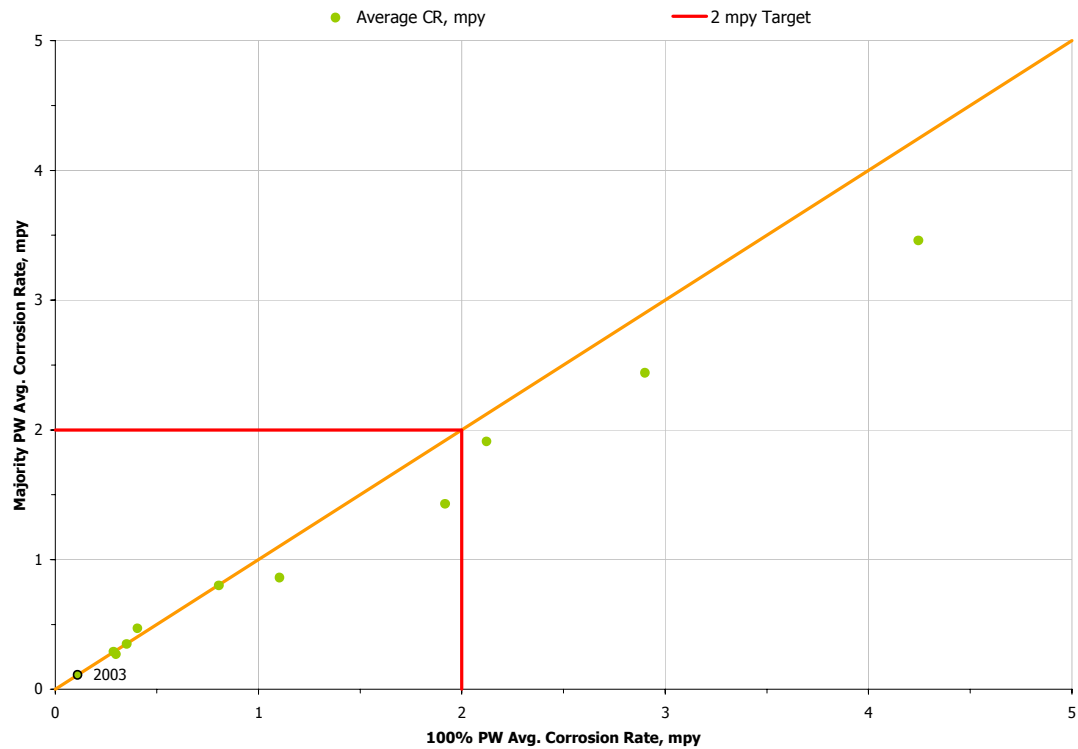
A comparison of the average corrosion rate for produced water between the 100% service and majority service is provided in GPB Figure C.7. The figure shows little difference between the data.



Section C Weight Loss Coupons and ER Probes



GPB Figure C.6 Corrosion Rates for Majority PW System



GPB Figure C.7 Comparison of Corrosion Rates for 100% and Majority PW

The overall improvement in the performance of the PW system from 2001 to date can be attributed primarily to two factors. First, there was a change in the upstream 3-phase continuous corrosion inhibitor in 2002 that gave more favorable partitioning characteristics to the water phase than the prior product. This had the effect of increasing the levels of corrosion inhibitor carried from the upstream system into the produced water distribution network. The second contributor was the expansion of corrosion mitigation programs specific to the PW system started in 2002. The program now includes limited inhibitor injection in the PW system at FS-1, FS-3, GC-1, GC-2 and GC-3.

### **Section C.2.3 Seawater Injection Well Lines**

The main corrosion mechanisms in the seawater (SW) injection systems are,

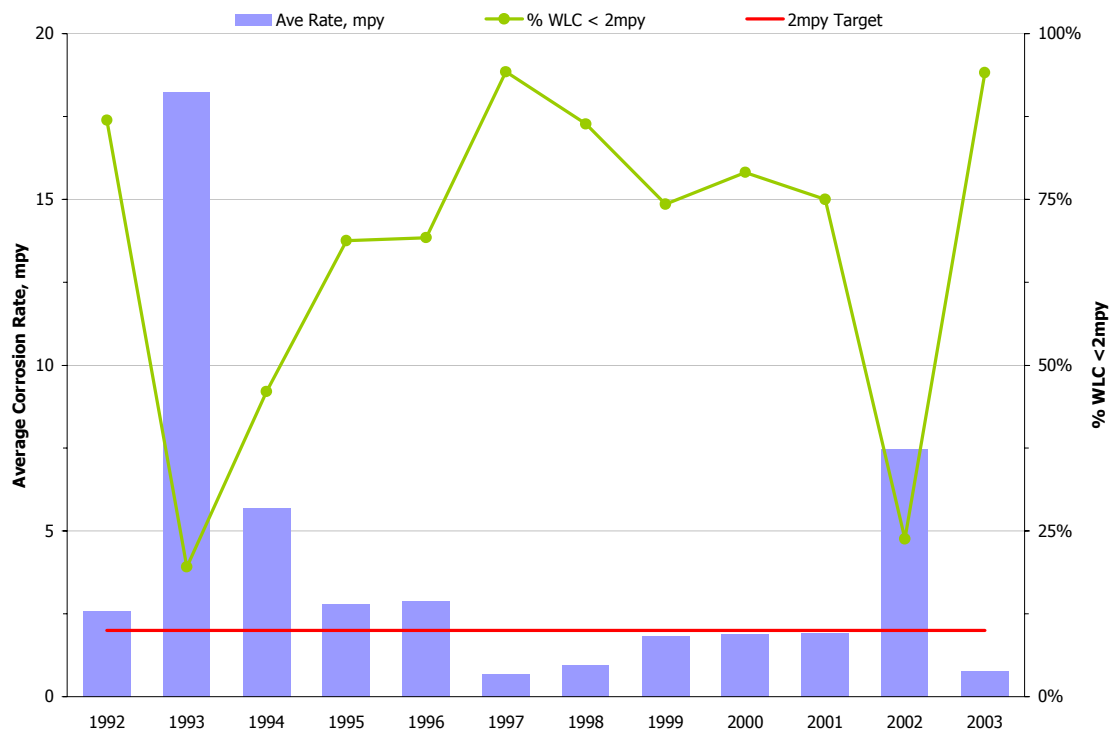
- Dissolved oxygen (DO) corrosion – This mechanism is mitigated by processing the seawater to remove the oxygen. Initial DO removal is achieved mechanically by vacuum stripping, which is then followed by chemical oxygen scavenging.
- Microbiological corrosion (MIC) – MIC is due to the action of anaerobic bacteria, and is mitigated by batch treatment with biocide, after processing to remove DO and prior to seawater transfer to the main cross country flow lines.

As with the PW system, the SW system data are presented as both 100% and majority service for the well line data, along with a comparison of general corrosion rates and pitting corrosion rates.

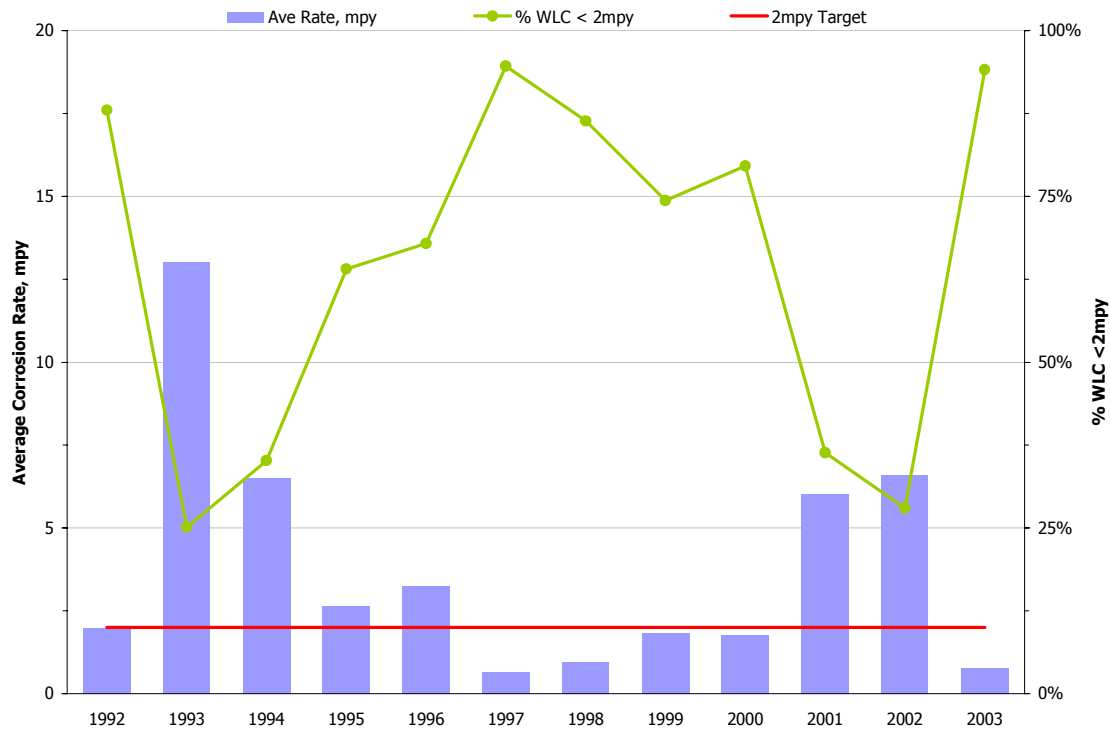
GPB Figure C.8 through GPB Figure C.10 show the corrosion rate trends in the SW system. For both 100% SW service and majority SW service, the general corrosion rates improved in 2003, reversing a 5-year trend.

It is believed the improvement is a result of implementation of the corrective actions outlined in the 2001 and 2002 Meet and Confer sessions with ADEC.

Section C Weight Loss Coupons and ER Probes

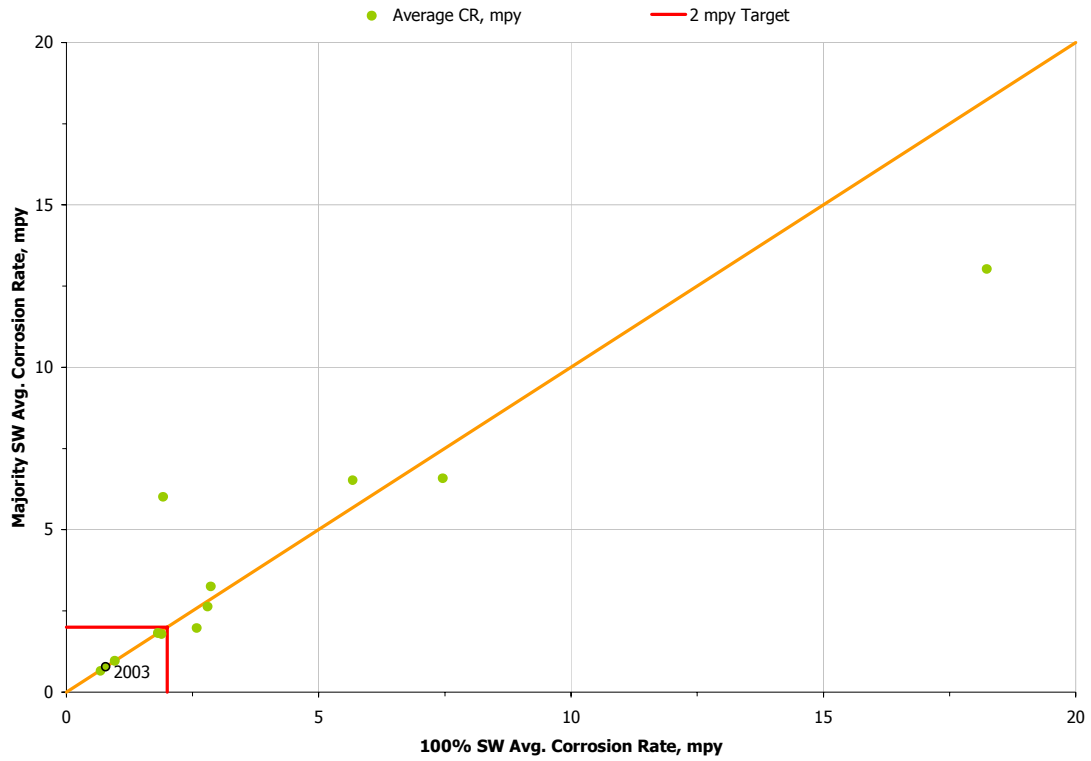


GPB Figure C.8 Corrosion Rate for 100% Seawater System

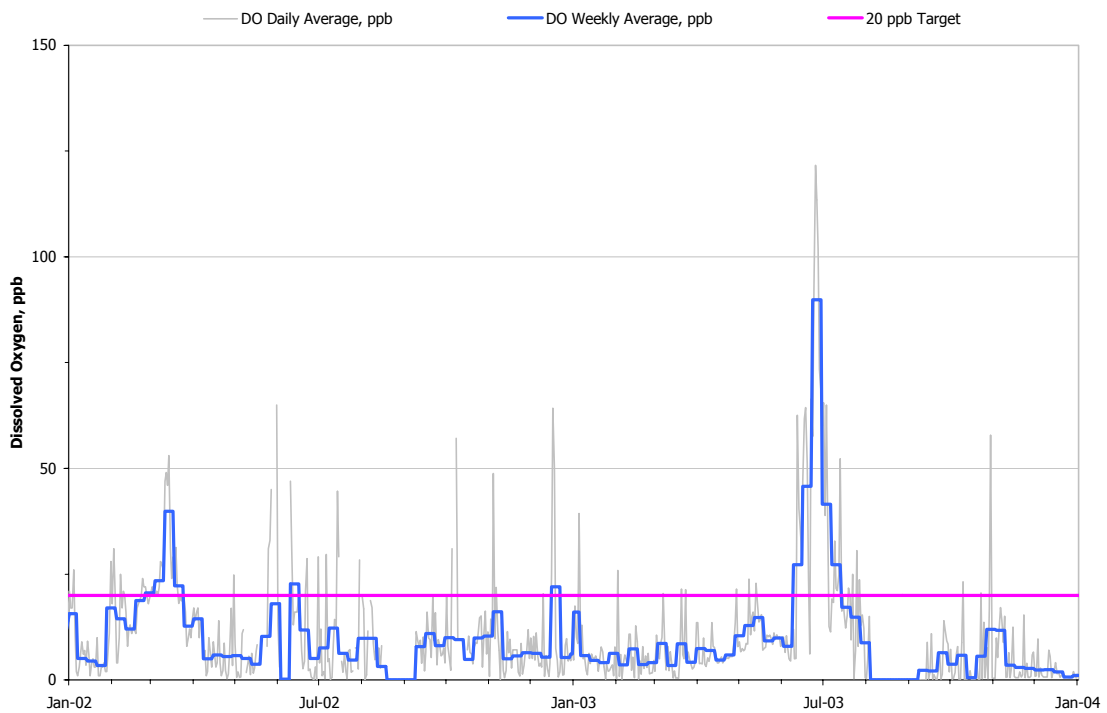


GPB Figure C.9 Corrosion Rates for Majority SW System

## Part 1 – Greater Prudhoe Bay Performance Unit



**GPB Figure C.10 Comparison of Corrosion Rates for 100% and Majority SW System**



**GPB Figure C.11 Dissolved Oxygen Control Performance for the Seawater System**

GPB Figure C.11 shows the daily and weekly average level of dissolved oxygen control in the seawater system through 2003. The DO excursion in summer 2003 was due to seasonal decreases in rates of the chemical oxygen scavenging reactions during periods of spring runoff and seawater turbidity. This was followed by a ~1 month shutdown to complete system upgrades for increased capacity. DO control improved markedly in the latter part of 2003, and diligent plant operation continues to deliver good DO control.

GPB Table C.1 summarizes the changes in the biocide treatment program for the SW system. Biocide dosage was increased in March 2003 by 50% at STP to increase the effectiveness in downstream parts of the seawater system. This action decreased the downstream coupon corrosion rates faster than expected. In December 2003 the glutaraldehyde/quaternary amine biocide was replaced with glutaraldehyde for operational reasons.

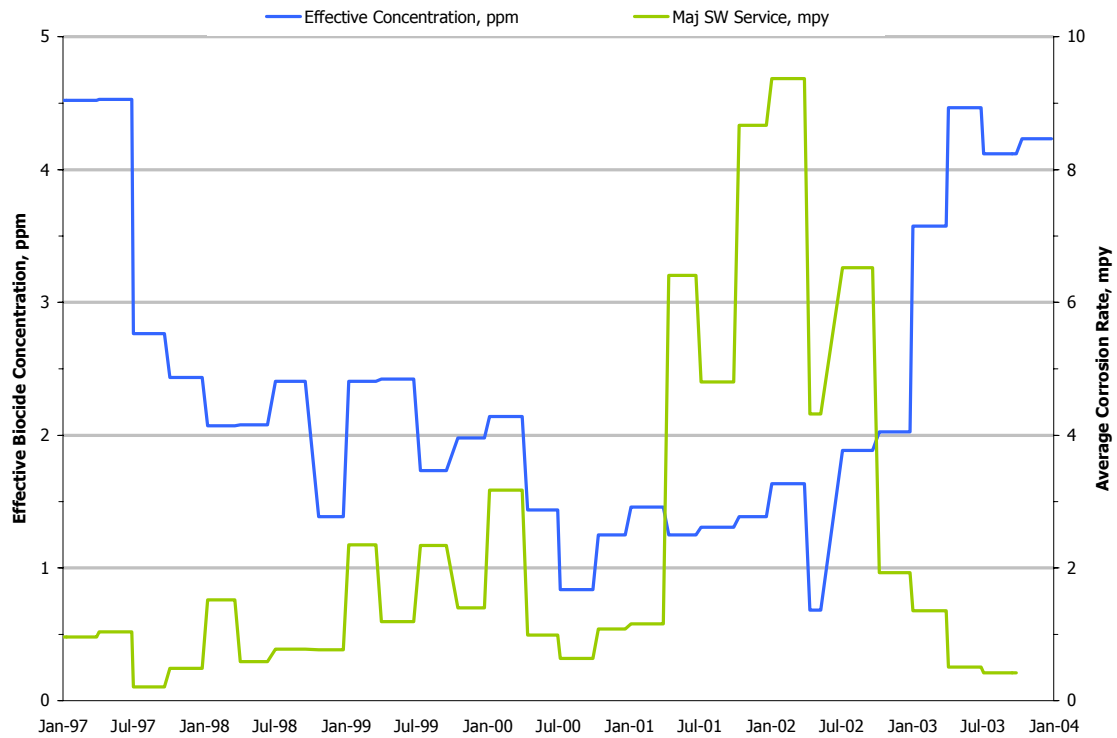
<b>From</b>	<b>To</b>	<b>ppm</b>	<b>Interval days</b>	<b>Product</b>
Jan-97	Jul-97	750	7	Glutaraldehyde
Jul-97	Feb-00	750	14	Glutaraldehyde
Feb-00	Aug-01	450	14	Glutaraldehyde/quaternary amine blend
Aug-01	Jul-02	500	14	Glutaraldehyde/quaternary amine blend
Jul-02	Dec-02	500	7	Glutaraldehyde/quaternary amine blend
Dec-02	Mar-03	500	7	Glutaraldehyde/quaternary amine blend
Mar-03	Dec-03	750	7	Glutaraldehyde/quaternary amine blend
Dec-03	Present	750	7	Glutaraldehyde

**GPB Table C.1 Biocide Treatment Concentration and Interval**

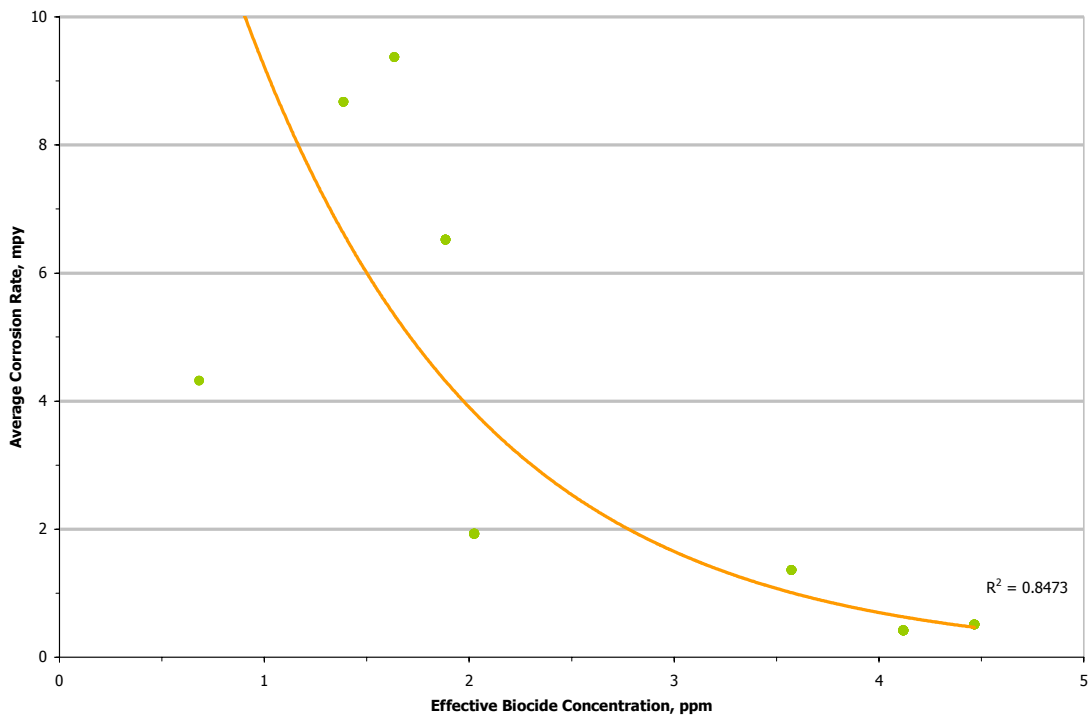
GPB Figure C.12 shows the corresponding effective concentration of biocide and the average corrosion rate for well line coupons in majority SW service. The beneficial effect of increasing the biocide injection concentration at STP is clearly depicted and helped to reduce seawater system corrosion rates below the 2 mpy target.

The effect of increasing biocide on the corrosion rates in the SW system are more clearly shown in GPB Figure C.13, which shows the correlation between the average corrosion rate and effective biocide concentration for 2001 through 2003.

## Part 1 – Greater Prudhoe Bay Performance Unit



**GPB Figure C.12 Biocide Treatment Concentration and Corrosion Rate**



**GPB Figure C.13 Average Corrosion Rate vs. Effective Concentration, 2001 - 2003**

In summary, improvements made from 2000 to 2003 in DO control and increased biocide injection rate have reduced corrosion rates in the seawater system. The data suggest progress has been made in returning the seawater system to control; however as with the produced water system, caution is warranted. Therefore, there will be an on-going effort in 2004 to assure that this trend is confirmed and continued. Should a long-term trend of reduced corrosion rates not be established then further corrective actions will be implemented.

### Section C.3 Electrical Resistance Probes

ER probes are installed in various locations to monitor corrosion rates in flow lines throughout GPB. ER probes show increases due to material loss from corrosion and the measurements are converted to provide corrosion rates in mils per year. ER probes are equipped with remote data collectors (RDC), which measure and record the metal loss data every 3 hours. This provides an adequate number of data points to assess corrosion rates while maximizing battery life in the units.

The type of ER probe used is a T-10 that has 5 mils (0.005") of usable metal thickness. All flow line ER probes are replaced based on a 1-year service life, or when one half the usable metal thickness has been consumed. This reduces false negative and false positive readings as a result of damaged or unresponsive probes.

ER probes are located on both the upstream (well pad) end and downstream (gathering center) end of flow lines located on the west side of GPB. On the east side, probes are only located on the downstream (flow station) end of flow lines.

ER probe data are collected in the field and uploaded to the corrosion and inspection database once per week. More frequent readings can be made to closely monitor suspect locations/readings. The target for ER probe corrosion rate is  $\leq 2$  mpy. Each ER probe with a corrosion rate greater than 2 mpy is evaluated to determine data validity. After verifying an increase in corrosion rates based on the probe data, a corrosion inhibitor increase may be recommended, refer to Section D.7.

GPB Table C.2 shows the number of probes with corrosion rates greater than target as compared to the number actioned dating back to 2001.

Year	% <2mpy	No. ER Probe > 2	No. ER Probes Actioned
2001	97%	193	6
2002	97%	137	6
2003	93%	138	21

**GPB Table C.2 Number of ER Probes >2mpy and Actioned**

- The 21 occurrences greater than 2 mpy in 2003 were mitigated with corrosion inhibitor rate increases – see Section H.1.5.

GPB Figure C.14 shows the number of ER probes and the percentage of time the ER probes were providing data. The number of flow lines monitored with ER probes has increased due to the addition of new probe locations and an increased emphasis on equipment maintenance.



**GPB Figure C.14 Equipment Monitored Using ER Probes**

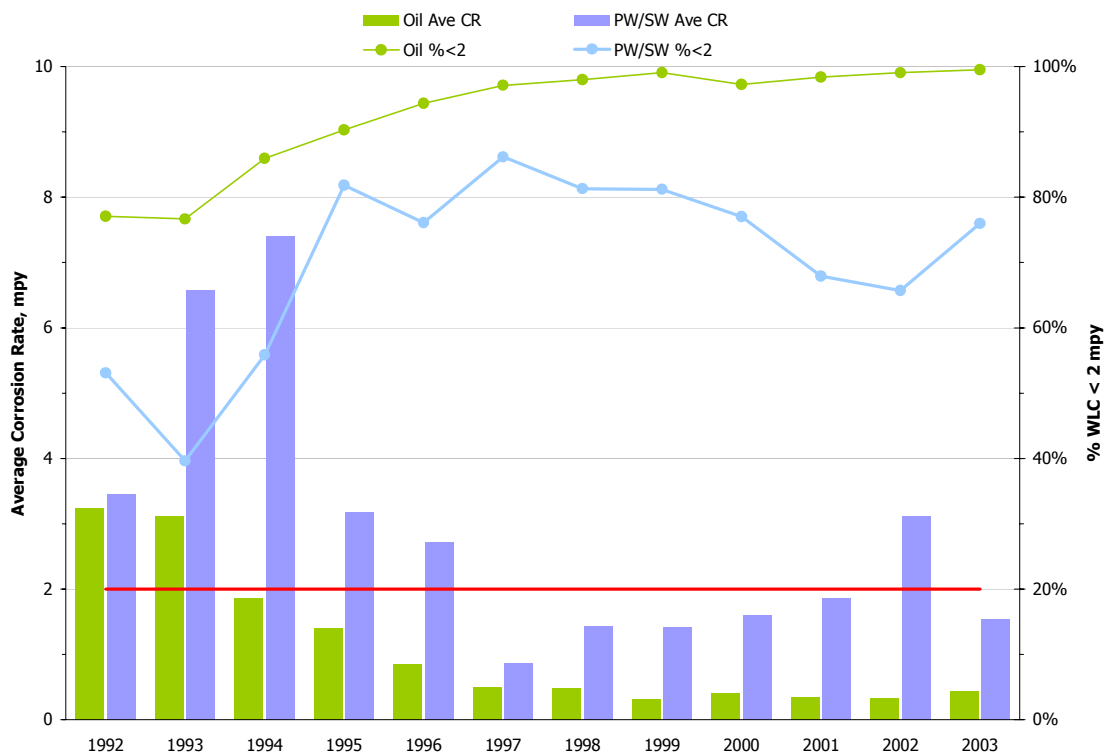
A significant effort was made in 2003 to improve reliability of data provided by the ER probe monitoring equipment. Equipment availability improved during 2003, from 95% at the beginning to 100% at year-end.

## Section C.4 1992 to Date Summary

### Section C.4.1 System by System Summary

This section provides system-by-system summary since 1992 for the major systems at GPB. GPB Figure C.15 shows the corrosion rate and corrosion target conformance since 1992. The performance in the 3-phase production system has improved slightly from 2002. The data set for water injection flow lines has been updated to include additional monitoring locations. The improvement from 2002 to 2003 is a result of the on-going corrective actions being implemented in the SW injection system.

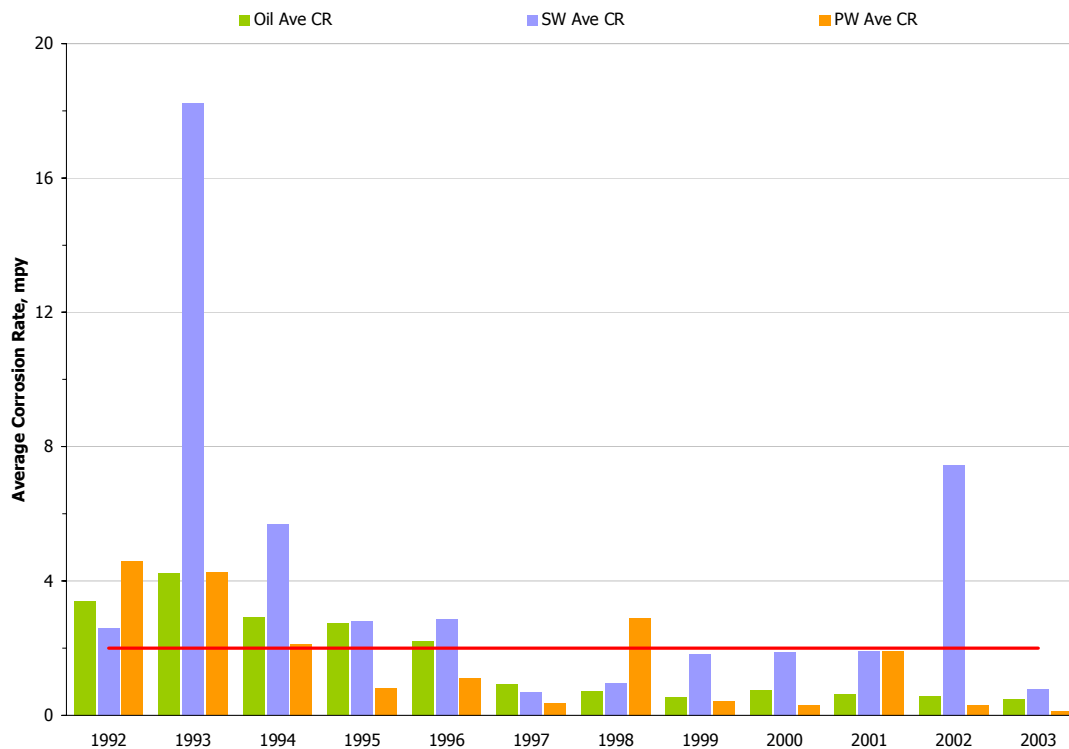




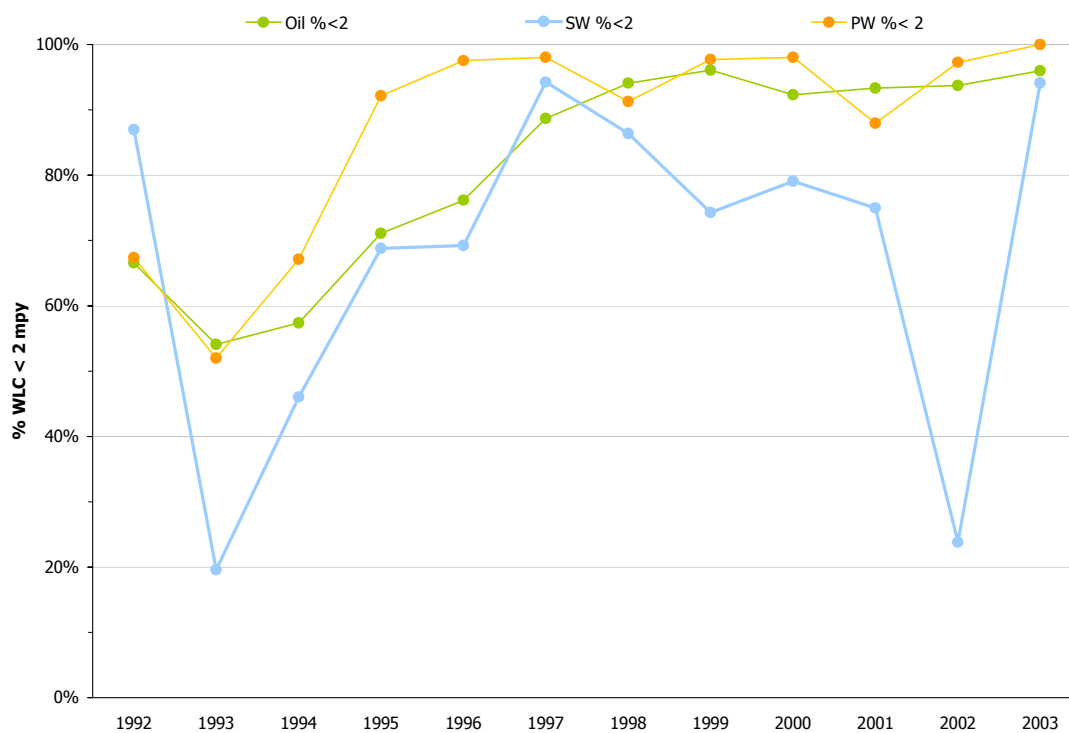
**GPB Figure C.15 Flow Line Corrosion Coupon Summary by Equipment and Service**

GPB Figure C.16 shows the corrosion rate and GPB Figure C.17 shows corrosion conformance for well lines. The well line 3-phase system has improved between 2002 and 2003. The produced water well lines corrosion performance continues to improve and corrosion rates decreased to their lowest level since 1992. The well lines in seawater service show a marked improvement in performance and in the level of conformance to the 2 mpy target. As previously discussed, there have been a number of changes made to the mitigation programs in the SW system.

## Part 1 – Greater Prudhoe Bay Performance Unit

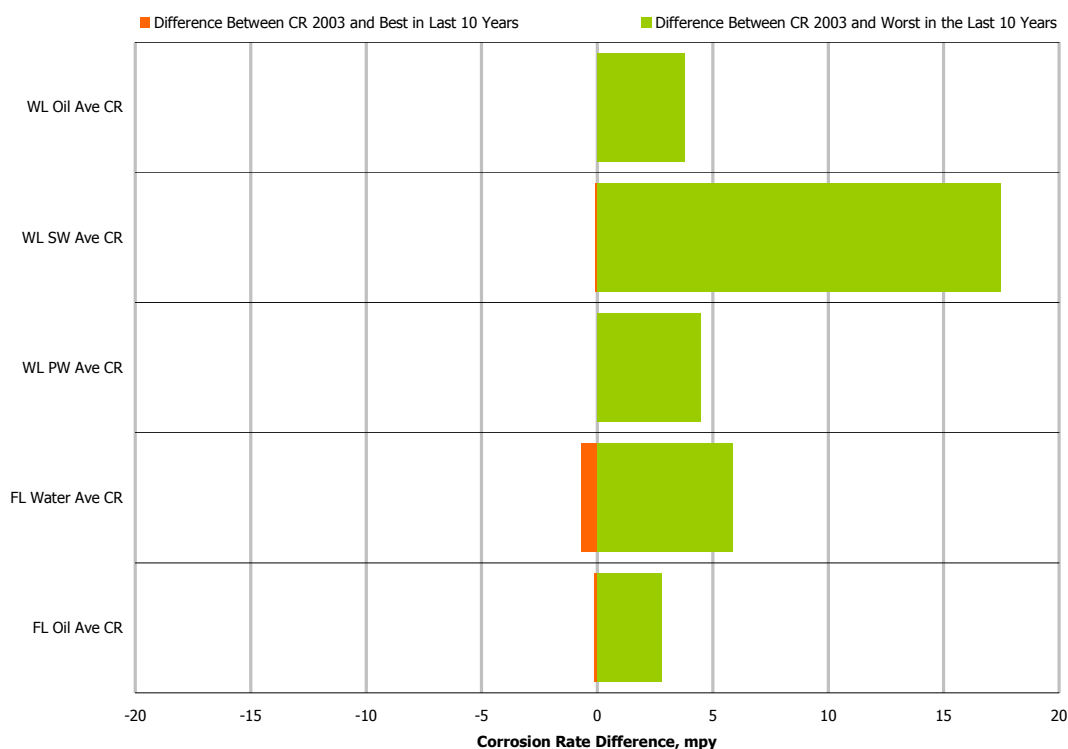


**GPB Figure C.16 Well Line Average Corrosion Rate Summary by Equipment and Service**



**GPB Figure C.17 Well line %<2mpy Summary by Equipment and Service**

In order to assess the relative performance of the corrosion management program today versus that of the last 11 years, GPB Table C.3 and GPB Figure C.18 were generated as a summary. The data show the difference between the 2003 WLC corrosion rate for each of the systems and the best, or lowest, WLC corrosion rate and the worst, or highest, WLC corrosion rate observed since 1992. This is an approximate measure of the successes and/or shortcomings of the program today versus the ~11-year history and highlights areas for attention. The results indicate the current level of corrosion control, as determined by weight loss coupons, is at or near the best levels of control in the last 11 years for each system.



**GPB Figure C.18 WLC Corrosion Rate Difference by Service and Type**

System	2003 CR mpy	Best mpy	(Best – 2003) mpy	Worst mpy	(Worst – 2003) Mpy
FL Oil Ave CR	0.43	0.32	-0.12	3.2	2.80
FL Water Ave CR	1.54	0.87	-0.67	9.34	7.80
WL PW Ave CR	0.11	0.11	0.00	4.61	4.50
WL SW Ave CR	0.78	0.68	-0.10	18	17.22
WL Oil Ave CR	0.47	0.47	0.00	4.3	3.83

**GPB Table C.3 WLC Corrosion Rate Difference by Service and Type**

In summary,

**Well Line Oil Service** – Significant improvements in performance occurred from 1992 to 1997 when the average corrosion rate (CR) was reduced from 3.6 to 1.0 mpy (~70% improvement) and conformance to the 2 mpy target was increased from 64% to 88% (~40% improvement). Since then, CR and target conformance performance has increased to the 2003 values of 0.5 mpy and 96% respectively. Continued improvements are expected due to corrosion inhibitor distribution optimization (individual target rates and expansion of continuous injection systems).

**Flow Line Oil Service** - Consistent with historical best performance, 99% of coupons pulled in 2003 were less than or equal to the corrosion control target of 2 mpy. Significant improvements in performance occurred from 1992 to 1997 when the average CR was reduced from 3.3 to 0.5 mpy (~85% improvement) and conformance to the 2 mpy target was increased from 77 to 97% (~25% improvement). Since then, CR and target conformance performance has improved to the 2003 values of 0.4 mpy and 99%, respectively.

**Flow Line Processed Oil** – These are the flow lines supplying processed hydrocarbon to Pump Station 1 and as might be expected for a very low water cut production stream, the corrosion rates are consistently very low with 100% of the coupons being reported as less than 2 mpy from 1995 to 2003.

**Well Line PW Service** – Average CR and percent conformance with the 2 mpy target achieved historical best performance at 0.1 mpy and 100%. The two excursions, 1998 and 2001, were likely the result of reduced system velocities and oil system corrosion inhibitor changes. Work continues in the evaluation of new the corrosion control techniques designed specifically for the PW system.

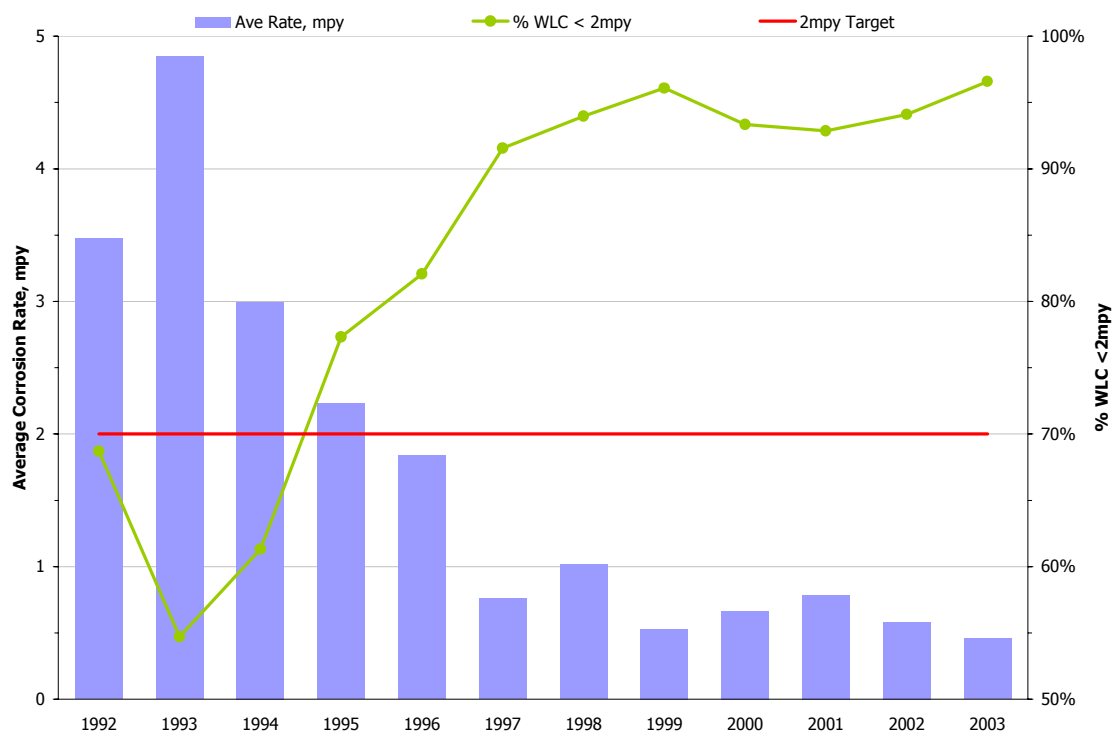
**Well Line SW Service** – Performance deteriorated from 1997 through 2002 with the average CR increased from 0.7 to 7.5 mpy. Average CR and percent conformance with the 2 mpy target rebounded in 2003 to 0.7 mpy and 94% respectively. This is a direct result of specific corrective actions that were implemented in 2001 and 2002. While these initial data are encouraging, it is probably too soon to be assured that the corrosion trend has been reversed. SW system corrosion control will continue to be a focus in 2004.

**Flow Line PW/SW Service** – Performance deteriorated from 1992 to 1994 when average CR increased from 3.5 to 7.4 mpy. However, significant improvements occurred from 1994 to 1997 when the average CR was reduced to 0.8 mpy. Since then, CR and target conformance degraded until 2003 when performance improved to 1.5 mpy and 76% respectively.

### Section C.4.2 Aggregate Summary

As an overall representation of the progress of improving corrosion control, GPB Figure C.19 shows the aggregate performance for all equipment and all services discussed in this report. The average corrosion rates have fallen by 80% from 2.3 mpy in 1995 to 0.5 mpy in 2003 and that the number of coupons meeting or beating the 2 mpy target has increased from 76% in 1995 to 97% in 2003.

It should be noted that the majority of the pipelines are in 3-phase service and hence these aggregate data are dominated by the performance of the 3-phase system.



**GPB Figure C.19 GPB Aggregate Performance**

For the GPB systems in aggregate, 2003 represents the best ever performance both in terms of average corrosion rates and percentage of WLC  $\leq$  2 mpy target.



## **Section D**

### **Chemical Optimization Activities**







## **Section D Chemical Optimization Activities**

### **Section D.1 Chemical Optimization**

Chemical optimization is an on-going process that encompasses a broad range of activities, from developing new corrosion inhibitors for improved performance, to the allocation of extra chemical for additional corrosion control. The following sections provide an update on chemical development, field wide chemical deployment, chemical usage and finally corrosion control.

### **Section D.2 Corrosion Inhibitor Development**

The development of new corrosion inhibitors starts in the research and development laboratories of the chemical suppliers where potential products are tested for effectiveness under a range of conditions designed to simulate production fluids. Once these preliminary test chemistries have passed the laboratory screening process, the promising products are tested under field conditions using dedicated test facilities at GPB. The test process is summarized in GPB Table D.1.

In 2003, a new standardized protocol for well line testing was developed. Approximately ten new products are tested each quarter on a small scale test using an individual well line with each test lasting ~2 days and using approximately 5 gallons of the corrosion inhibitor under evaluation. Products that successfully pass the well line test program are then considered for a large-scale field trial.

The large-scale field trial involves converting between one and three well pads to the test product for 90 days and using 20-40,000 gallons of test chemical. This enables corrosion probe, coupon, and inspection data to be generated to verify the test product's effectiveness as a corrosion inhibitor. The large-scale field trial also allows assessment of the impact of the product on oil separation and stabilization process. Progress is being made in developing a new, standardized protocol for more rapid verification of a product's effectiveness as a corrosion inhibitor.

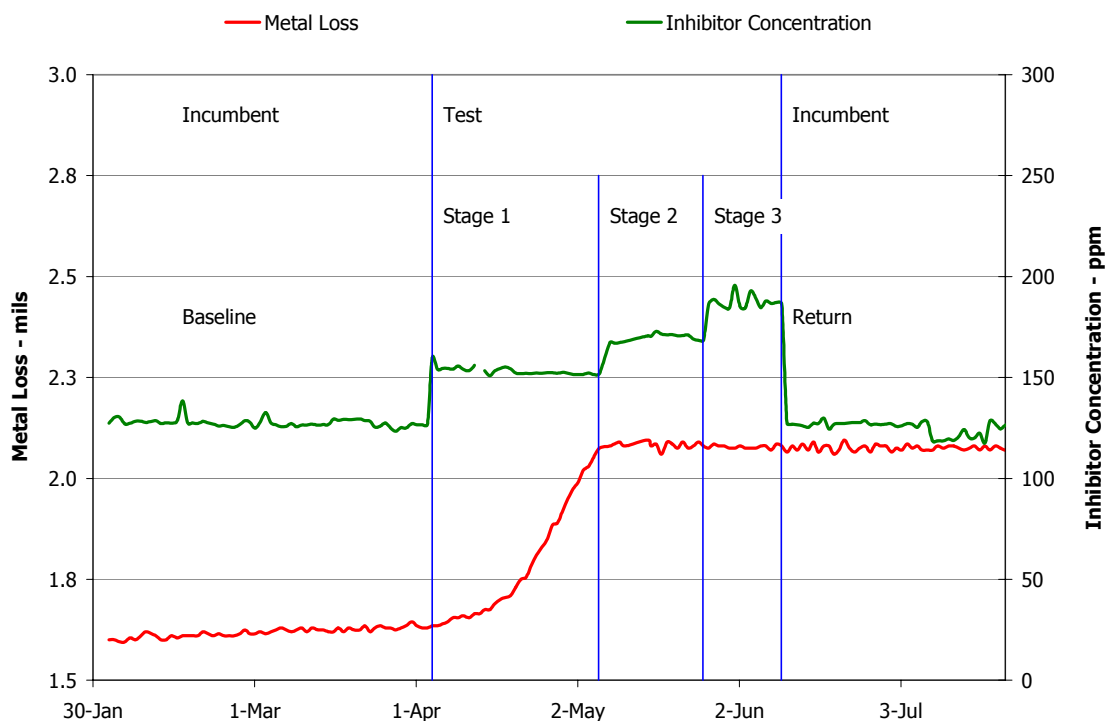
<b>Location</b>	<b>Test</b>	<b>Description</b>
Laboratory	Wheel-box Test	Performance of new potential corrosion inhibitor actives is compared to high performing actives. The test conditions simulate GPB and the test is run for 24 hours. Performance is determined by coupon weight loss.
	Kettle Test	This investigates the ability of an inhibitor formulation to partition from an oil phase into a brine phase under stagnant conditions. Test duration is 16 hours and corrosion rate is determined by linear polarization resistance (LPR) probes.
	HP Autoclave	This method determines the performance of inhibitors under high pressure and high temperature conditions. Monitoring method is by either coupon weight loss measurements or LPR. Test duration varies from 1 to 7 days.
	Jet Impingement	A once-through jet impingement configuration evaluates the performance of an inhibitor formulation under extremely high shear conditions. The persistency of the inhibitor film can also be determined. Test duration is one hour and corrosion rate is determined by LPR measurements.
	Flow Loop Test	The ultimate laboratory scale test that simulates temperature, pressure and flow conditions including velocity and water cut. Typical test duration is 24 hours and corrosion rate is determined by LPR measurements.
Field	Well Line Test	Dedicated test well lines are used at GPB as the first step in the field-testing process. Typically 5 gals of chemical used with a test duration of 2 days.
	Large Scale Test	1 to 3 well pads using 20-40,000 gallons of corrosion inhibitor with a test duration of 90+ days. Allows the evaluation of corrosion inhibitor performance by ER, WLC, and inspection, as well as impact of product on separation plant performance.
	Evaluation	Products are evaluated against both technical performance and cost effectiveness criteria in order to assess if there is an overall improvement in performance.
GPB	Implementation	Once a decision has been made to convert the field to a new product, additional precautions are taken with additional corrosion monitoring and plant performance evaluations in order to assure product efficacy.

**GPB Table D.1 Summary Description of the Typical Test Program Components**

As an example, the ER probe results from a typical cross-country flow line test are shown in GPB Table D.2 and are summarized in GPB Figure D.1. Based on these data, the test chemical in this example was not cost effective and therefore was not utilized across the field.

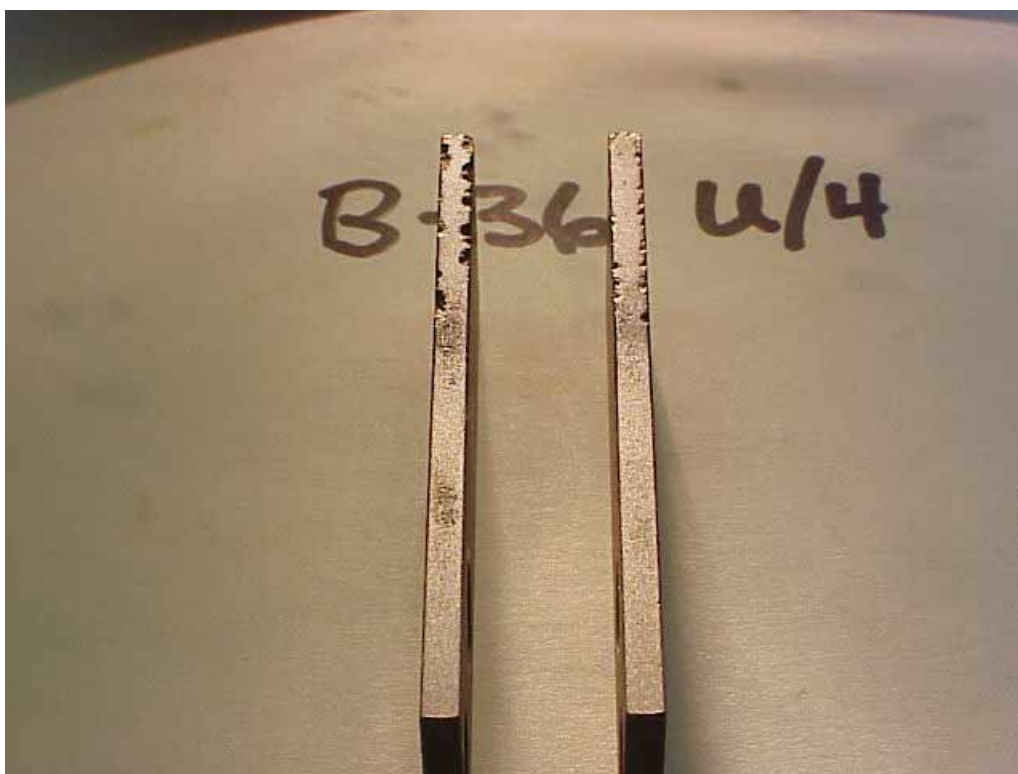
Status	Chemical	Conc. ppm	CR, mpy	Notes/Comments
Baseline	Incumbent	130	0.2	
Stage 1	Test	150	8.1	Even at a higher dose rate the test chemical was unable to inhibit corrosion to the same level as the incumbent.
Stage 2	Test	170	2.0	Reduces corrosion rate.
Stage 3	Test	190	0.8	Dose rate was increased in order to achieve the same level of corrosion control as the incumbent. At this increased level of corrosion inhibition the test product was uneconomic and the test was terminated.
Return	Incumbent	130	0.1	Re-inject the incumbent product and corrosion rates return to the same level as those prior to the test.

**GPB Table D.2 Flow line Test Program Result Summary**



**GPB Figure D.1 ER Probe Chemical Optimization Test**

A second example, utilizes the output from the weight loss coupon program. This example from a test performed in 2001, demonstrates the need/value of multiple monitoring techniques when evaluating corrosion inhibitor performance. The trial product was tested for a 90-day period with no negative response observed by the ER probes. However, after the 90-day test period the corrosion coupons were pulled and showed relatively high general corrosion and pitting rates - see GPB Figure D.2. The product evaluated was a failure and the incumbent product was re-instated based on the coupon results. Corrosion inhibitor tests use all the monitoring tools available such as corrosion probes, coupons, and inspection data to determine corrosion control performance. In addition, the corrosion inhibitor is evaluated for plant production performance to show compatibility with the separation process.

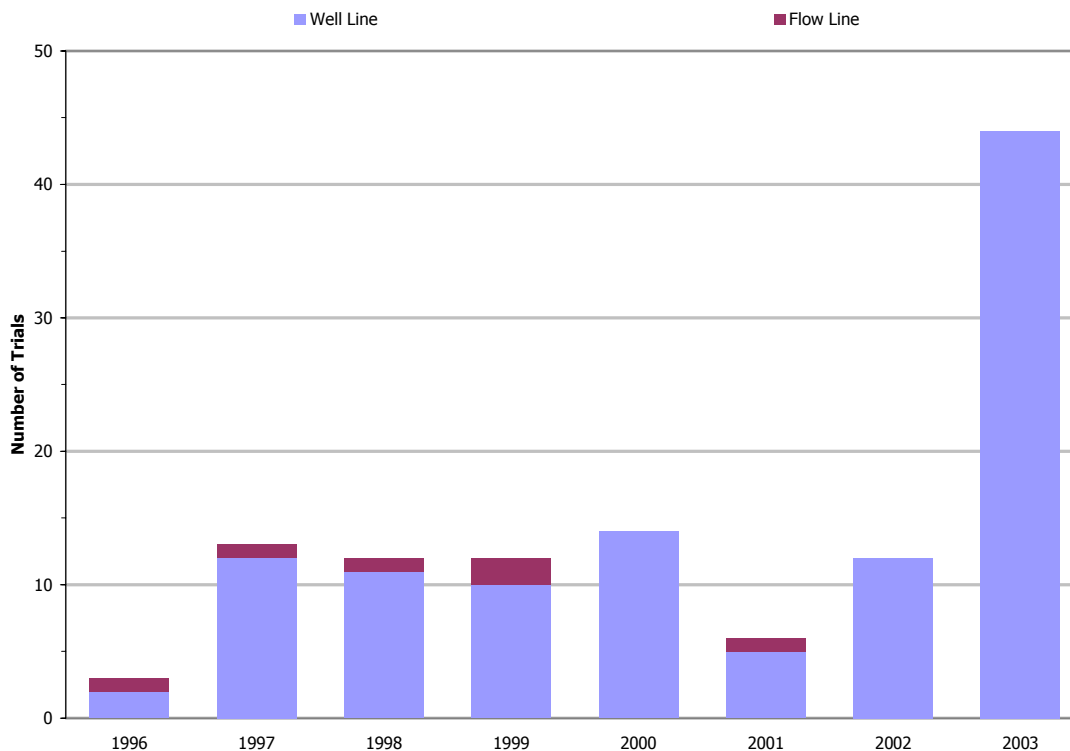


**GPB Figure D.2 Corrosion coupons pulled after an 'unsuccessful' chemical trial**

### **Section D.3 Corrosion Inhibitor Testing**

GPB Figure D.3 summarizes the number of well line and flow line tests which have been completed since 1996. The level of well line test activity has increased during 2003 due to a change in the screening protocol, which reduced the time required per test. The combined number of well line and flow line tests has increased from ~10-14 per year to more than 40 during 2003.

The data prior to 2000 are incomplete and represents the test work completed on the heritage WOA only. This level of activity represents a substantial investment of resources towards the development of new and more effective corrosion inhibitors.



**GPB Figure D.3 Number of Well Line and Flow line Tests**

The criteria to move from a well line test to flow line testing are rigorous and no candidates from 2002 or 2003 progressed to a large scale flow line test.

#### **Section D.4 Field Wide Corrosion Inhibitor Deployment**

The chemical development and testing program has been highly successful in recent years, with 18 new products being developed for use in the continuous wellhead inhibition program since 1995. All these changes over the last 9 years represent a significant improvement in overall corrosion control performance.

GPB Table D.3 summarizes the changes in corrosion inhibitor products since 1995. The table does not include test products which did not make it to field wide usage. In addition, the summary table does not include summer versions of products that differ only in pour point from the winter version shown in the table.

Supplier	Chemical	1995	1996	1997	1998	1999	2000	2001	2002	2003
Nalco Exxon	EC1110A									
Nalco Exxon	EC1259									
Nalco Exxon	97VD129									
Nalco Exxon	98VD118									
ONDEO Nalco	99VD049									
ONDEO Nalco	01VD017									
ONDEO Nalco	01VD121									
Champion	RU205									
Champion	RU210									
Champion	RU223									
Champion	RU258									
Champion	RU271									
Champion	RU126A									
Champion	RU256 <sup>1</sup>									

<sup>1</sup> Used for the batch treatment of well lines while the remaining chemicals are all used for continuous application

**GPB Table D.3 Summary of the Chemical Deployment History**

## Section D.5 Corrosion Inhibitor Usage and Concentration

Another measure of chemical optimization is the amount of corrosion inhibitor used relative to the volume of water produced from the reservoir. GPB Table D.4 summarizes the annual water production, corrosion inhibitor volumes, and concentrations since 1995. The inhibitor volumes are expressed as a 'winter product equivalent', i.e. the lower volumes of highly concentrated chemical used during the summer have been normalized to the winter equivalent.

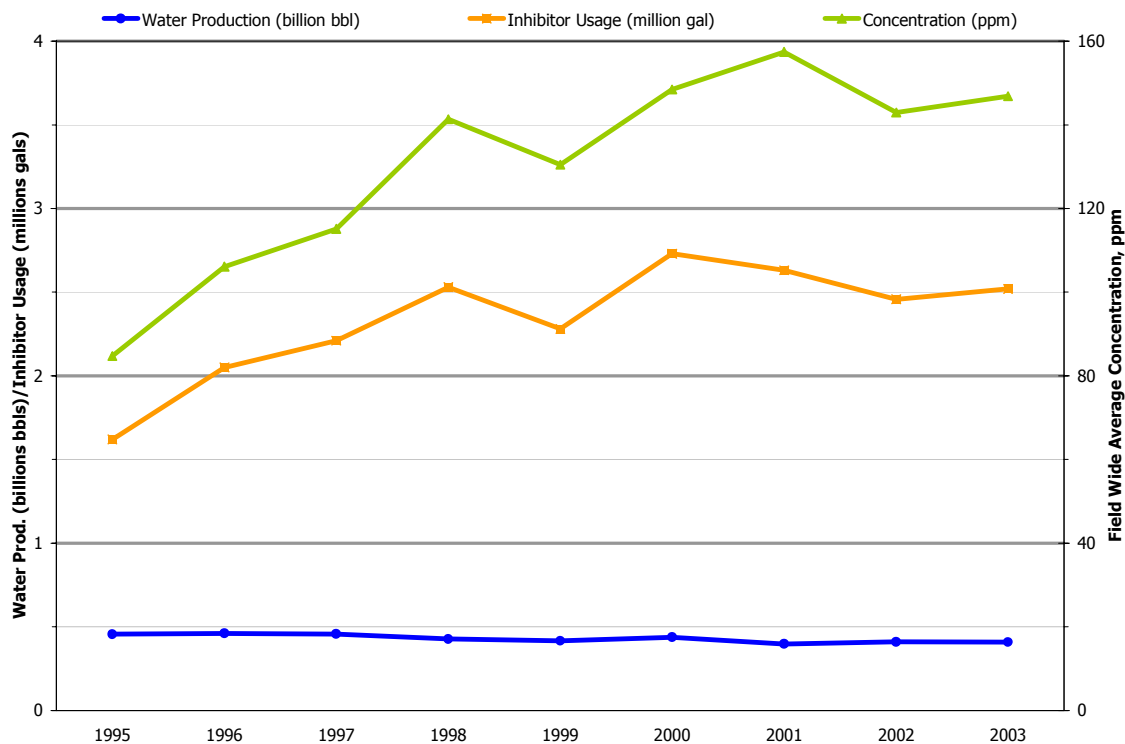
The concentration of inhibitor in the water phase provides a relative measure of the effectiveness of the chemical used to control corrosion. However, such data can be misleading as the types of corrosion inhibitors used can vary from year to year (GPB Table D.3). As more effective chemicals are developed, volumes and concentrations will change depending on the individual product's performance characteristics. There has also been a shift from batch treatments to continuous injection of chemical at the wellhead. The latter is more efficient in terms of protection achieved per gallon of chemical and therefore lower chemical usage would be expected. However, the ultimate measure of whether or not enough corrosion inhibitor is used can only be determined by consideration of other factors such as corrosion monitoring data and/or the amount of active corrosion detected by the inspection program.

<b>Year</b>	<b>H<sub>2</sub>O Production</b> 10 <sup>6</sup> bbl/yr	<b>Water Cut</b> %	<b>CI Usage</b> 10 <sup>6</sup> gal/yr	<b>CI Concentration</b> ppm
1995	455	59	1.62	85
1996	460	62	2.05	106
1997	457	62	2.21	115
1998	426	66	2.53	141
1999	416	68	2.28	130
2000	438	70	2.73	148
2001	398	70	2.63	157
2002	407	71	2.45	143
2003	408	72	2.52	147

**GPB Table D.4 Summary of the Chemical Usage History**

The advances in the development of more effective corrosion inhibitors is counteracted by the increasing water cuts associated with an ageing oil field and increased flow velocities due to increased gas rates. These changes generally increase the amount of chemical required to control corrosion. As GPB Figure D.4 shows, the volume of corrosion inhibitor has increased since 1995 while the water volumes have remained relatively constant.

The metrics in GPB Figure D.4 deal with chemical usage at the field level but much of the chemical optimization activity focuses on injecting the correct amount of corrosion inhibitor to each piece of equipment. The inhibitor requirement is driven by factors such as water cut, water volume, flow regime, and condition of the equipment and varies over a wide range, from a few parts per million (ppm) to several hundred ppm. For 2003 the target chemical usage was 2.53 million gallons as compared to actual usage of 2.52 million gallons; or 99.6% of the target volume.



GPB Figure D.4 Field Wide Chemical Usage

## Section D.6 Corrosion Inhibition and Corrosion Rate Correlation

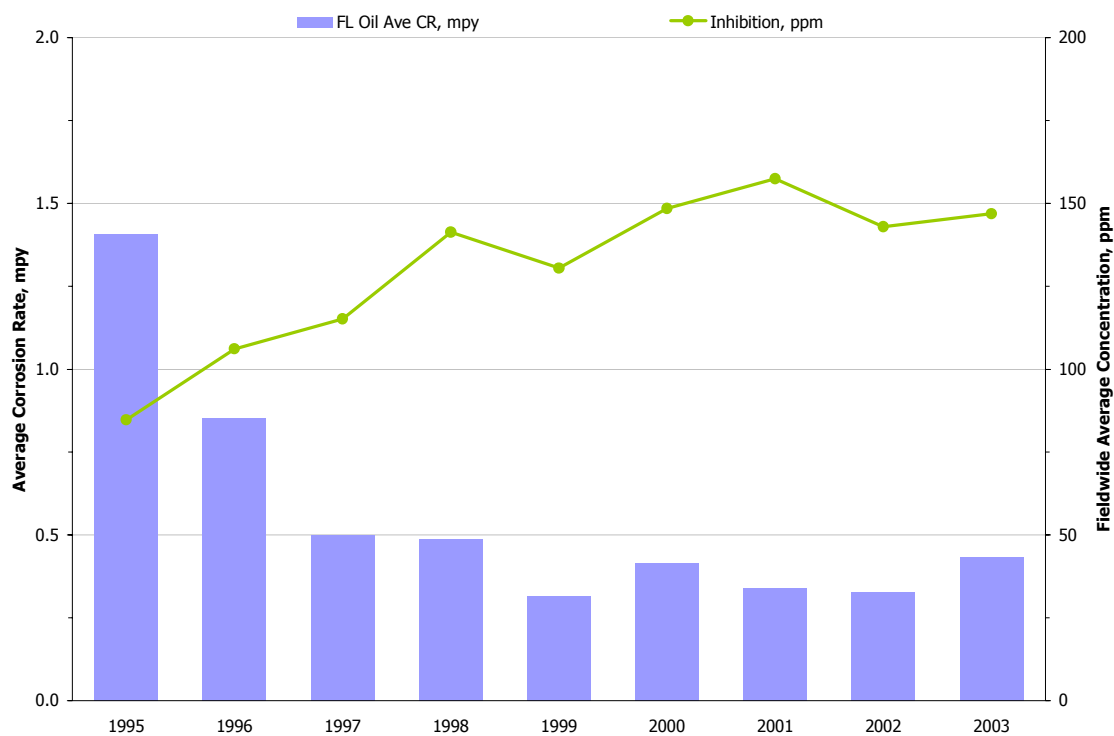
As discussed in the Section C.1, the reduction in corrosion rates in the 3-phase production system flow lines and well lines are largely attributable to the implementation of an aggressive corrosion inhibition program across GPB.

GPB Figure D.5 shows the correlation between the increased level of corrosion inhibitor and the reduction in average corrosion rate from 1995. As might be expected, the decline in average corrosion rate correlates with the increase in corrosion inhibition levels over time. The inhibition levels have increased approximately 70% from 1995 to 2003, with a field-wide average concentration of 85 ppm to 147 ppm. As a result the corrosion rates have fallen from 1.4 mpy in 1995 to 0.4 mpy in 2003.

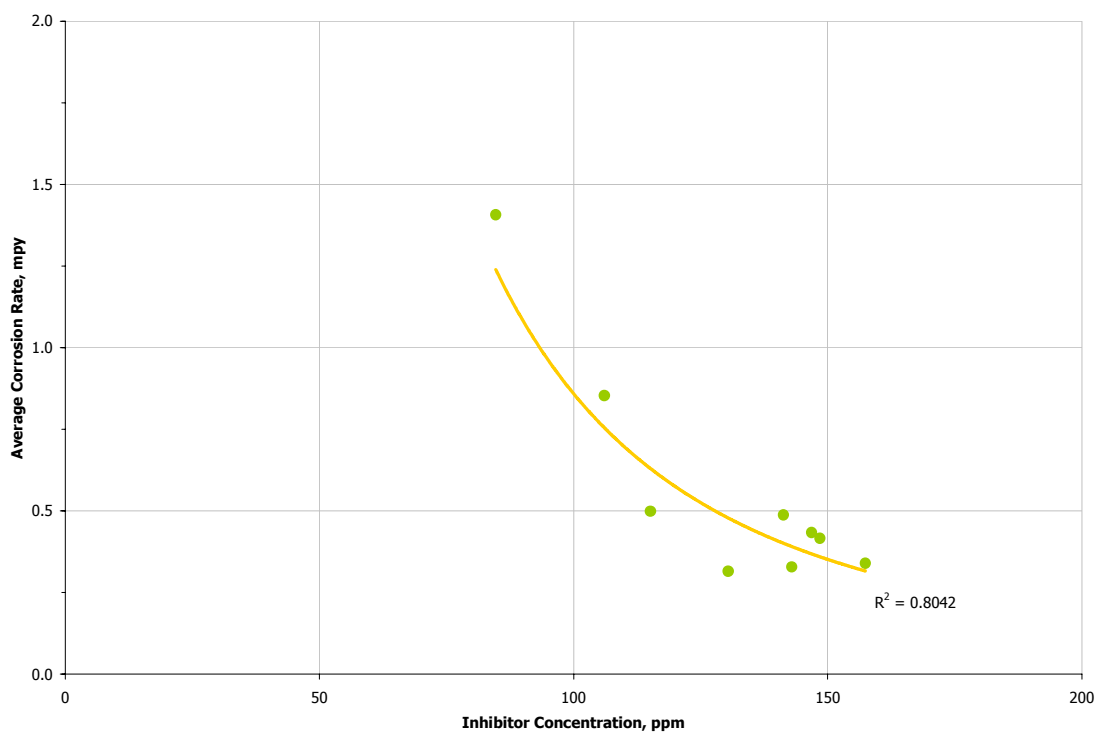
GPB Figure D.6 shows the annual field-wide average corrosion inhibitor concentrations versus annual average corrosion rates for 3-phase production flow lines. The figure shows how additional corrosion inhibitor has reduced the average corrosion rate through time, but also shows an inherent limitation of corrosion inhibition as the minimum corrosion rate (or maximum corrosion inhibitor efficiency) is approaching an asymptote of ~0.25 mpy.



## Section D Chemical Optimization Activities



**GPB Figure D.5 Average Corrosion Rate Versus Inhibitor Concentration**

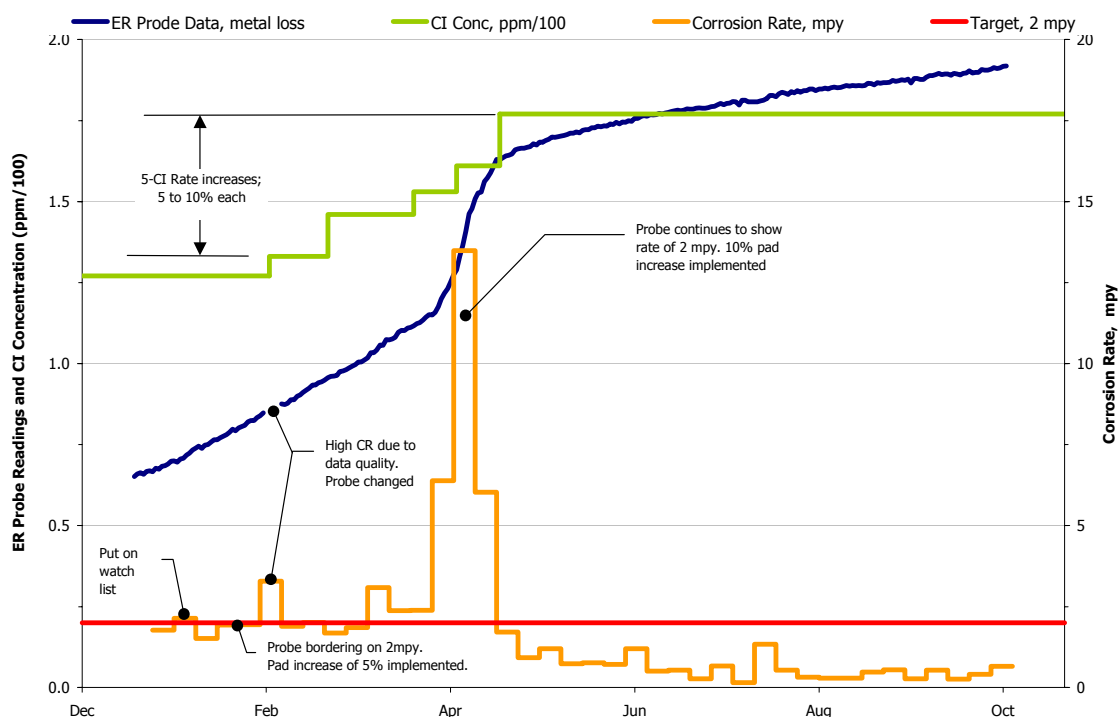


**GPB Figure D.6 Corrosion Inhibitor Concentration vs. Average Corrosion Rate**

## Section D.7 ER Probe and Corrosion Inhibitor Response

This section describes, by example, the methodology by which corrosion inhibitor concentration is increased as a result of corrosion monitoring through the use of ER probes. ER probes are in use across GPB on the large diameter 3-phase production flow lines.

GPB Figure D.7 and GPB Table D.5 illustrate the use of ER probes in managing changing corrosion conditions in a large diameter flow lines. GPB Figure D.7 shows the ER probe readings and derived corrosion rates, over a period of approximately 10 months in 2003. For the first 10 weeks the measured corrosion rate is bordering on 2 mpy and a 5% increase in CI is implemented. In early February the existing ER probe was replaced due to data quality issues. In mid March another increase of CI was implemented based on ER probe corrosion rate. During April and part of May, the CR still exceeded the target and two additional CI increases were implemented. Finally in mid-May, the CR falls below the 2 mpy target and the CI remains at the increased concentration.



GPB Figure D.7 Corrosion Inhibitor Concentration vs. Corrosion Rate

<b>Time Period</b>	<b>Comments</b>
14-Jan	Probe placed on watch list
14-Jan to Feb 11	Probe at or near 2 mpy, 5% increase in pad CI target
14-Feb	Poor data quality, ER probe replaced.
18-Feb to 21-Mar	Probe continues to show rate >2mpy, 10% increase in pad CI target
21-Mar to 30 Apr	Probe continues to show rate >2mpy, 10% increase in pad CI target
01-May to 01-Oct	Probe shows rate <2mpy, No adjustments to CI target

**GPB Table D.5 Corrosion Inhibitor Concentration vs. Corrosion Rate**

### **Section D.8 Chemical Optimization Summary**

In summary, chemical optimization covers a number of different areas from chemical testing and development to field-wide deployment of new products delivering improved levels of corrosion control more cost effectively. However, all this activity is ultimately directed toward one end — the reduction in corrosion rate. The effectiveness of the chemical optimization program in delivering improved corrosion rates is clearly demonstrated.



## **Section E**

### **External/Internal Inspection**





## **Section E External/Internal Inspection**

The inspection program covers the piping, piping components, pressure vessels and tanks across GPB. Radiographic imaging or ultrasonic flaw evaluation makes up the majority of inspection techniques. However, there are some specialized techniques in use for specific applications. The details for these techniques are shown in GPB Table B.11.

A number of factors contribute to the selection and allocation of inspection resources including, but not limited to, current equipment condition, current known rate (from inspection or corrosion monitoring) of wastage, operational risks associated with the fluids being transported, active or passive corrosion mitigation, and design and age of the equipment.

### **Section E.1 External Inspection**

This section summarizes the inspections performed to detect external corrosion and the results of those inspections. External corrosion is primarily associated with water ingress into the pipeline thermal insulation, in particular, at the field-applied insulation joints (weld packs).

The pipelines are generally uncoated carbon steel and are therefore vulnerable to external corrosion under the insulation (CUI) if water comes into contact with the pipe surface. The pipelines are constructed from either single or double joints (40 or 80 ft. long) with a shop-applied polyurethane insulation protected with a galvanized wrapping. The area around the girth welds are insulated with 'weld packs.' The detailed design of weld packs varies but all are prone to water ingress.

The main challenge in managing CUI is the detection of the external corrosion damage. Water ingress into the weld packs is a random process and therefore it is difficult to apply highly specific rules to target the inspection program.

GPB Table E.1 summarizes the CUI inspection program for the period 1995 to 2003 broken out by service and equipment type, well line and flow line, and the aggregate of both data sets.

These data suggest there is some dependence of external corrosion occurrence based on service type. This dependence is driven in part by the difference in operating temperature between these services. However, as much variability in damage occurrence is found based on the location and orientation of the weld-pack location.

<b>Service</b>	<b>Flow Line</b>			<b>Well Line</b>		
	<b># Insp.</b>	<b># Corr</b>	<b>% Corr</b>	<b># Insp.</b>	<b># Corr</b>	<b>% Corr</b>
3 Phase	34,437	2,391	7%	37,208	1,375	4%
Export	2,615	130	5%	-	-	-
Gas	45,083	1,921	4%	14,660	192	1%
Other	61	3	5%	275	24	9%
Water	19,196	1,655	9%	5,993	223	4%
<b>Total</b>	<b>101,392</b>	<b>6,100</b>	<b>6%</b>	<b>58,136</b>	<b>1,814</b>	<b>3%</b>

<b>Service</b>	<b>Aggregate</b>		
	<b># Insp.</b>	<b># Corr</b>	<b>% Corr</b>
3 Phase	71,645	3,766	5%
Export	2,615	130	5%
Gas	59,743	2,113	4%
Other	336	27	8%
Water	25,189	1,878	7%
<b>Total</b>	<b>159,528</b>	<b>7,914</b>	<b>5%</b>

**GPB Table E.1 CUI Inspections by Service Type, 1995-2003**

GPB Table E.2 shows the distribution of insulation joint types based on a sample of ~50,000 locations. For each specified joint type, there is an associated CUI incident rate. These data show there is as much variability in the CUI incident rate between the insulation joint configurations as there is associated with the service type. This suggests that the joint configuration and insulation joint location, along with age, have as much influence on the occurrence of external corrosion at weld-packs compared to the service type and operating temperature.



<b>GPB Joint Design</b>	<b>Joint Type Freq</b>	<b>CUI Incident Rate</b>
Anchor Joint	4.4%	2.8%
Damaged Insul	8.4%	2.0%
Damaged Weld Pack Insul	0.1%	2.4%
Ell Anchor Joint	0.1%	6.8%
Ell Bottom Elev	3.6%	6.3%
Ell Bottom Elev Saddle	0.5%	9.9%
Ell Horiz Saddle	1.0%	8.4%
Ell Horizontal	10.1%	3.8%
Ell Top Elev	2.6%	1.3%
Ell Top Elev Saddle	0.3%	4.5%
Mid-Span Weld Pack	56.4%	1.8%
Saddle Joint	11.1%	3.6%
Vertical Joint	0.1%	5.3%
Wall Penetration	1.2%	1.4%
<b>Average CUI Incident Rate</b>		<b>2.5%</b>

**GPB Table E.2 CUI Incident Rate by Joint Type**

In order to manage CUI, a recurring inspection program has been implemented as the best method to identify equipment and locations susceptible to CUI. Prioritization of inspection surveys is determined by configuration, average temperature of the equipment, age of equipment, health, safety, environment (HSE), and/or the last time a complete inspection was completed. As a result of findings from inspections, the extent or recurring frequency of any additional examinations is determined.

The CUI program covers all cross-country flow lines and well lines. There are approximately 300,000 weld packs at GPB, of which approximately 200,000 are off-pad and 100,000 are on-pad.

### **Section E.1.1 External Inspection Program Results**

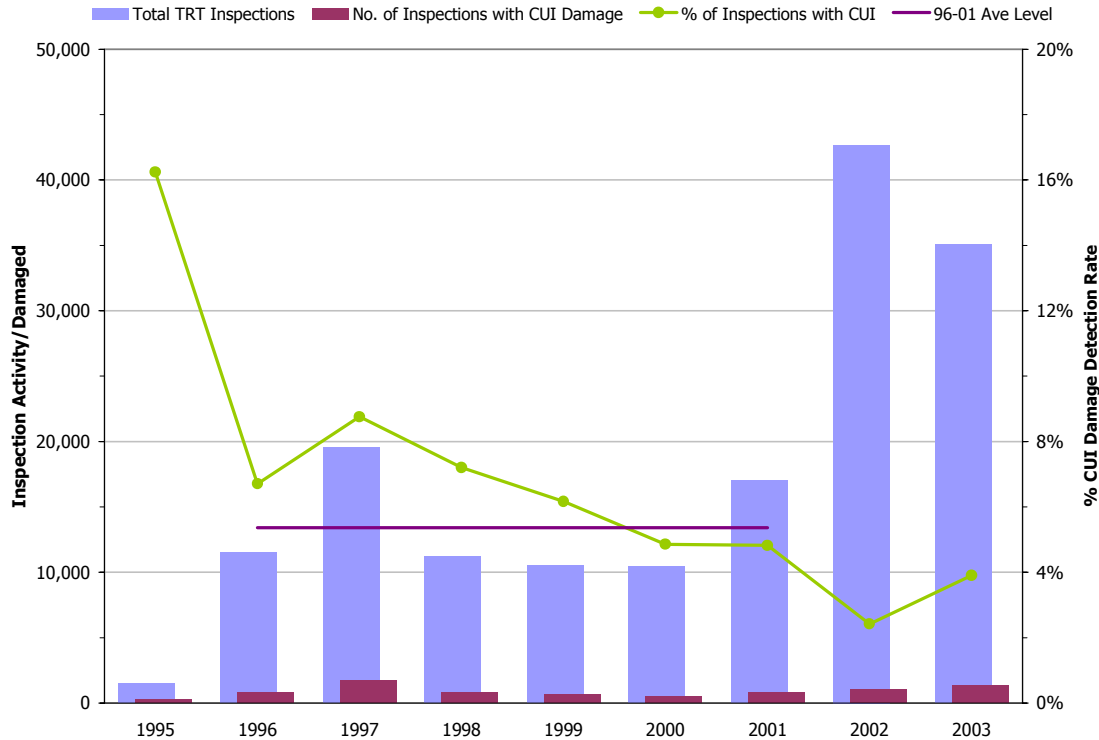
GPB Table E.3 and GPB Figure E.1 show the number and results of the external corrosion inspections performed from 1995 through 2003. The data includes all

the Tangential Radiographic (TRT) techniques applied to detect external corrosion, including Automated-TRT (ATRT), and C-Arm Fluoroscopy (CTRT).

	1995	1996	1997	1998	1999	2000	2001	2002	2003
<b>Well Line</b>									
Activity Level	-	36	1,680	946	2,376	5,257	13,071	23,949	10,821
Corrosion Detected	-	6	234	66	75	241	711	342	139
%Corroded	-	17%	14%	7%	3%	5%	5%	1%	1%
<b>Flow Line</b>									
Activity Level	1,508	11,461	17,866	10,289	8,136	5,180	3,966	18,727	24,258
Corrosion Detected	245	765	1,477	743	573	266	110	690	1,231
%Corroded	16%	7%	8%	7%	7%	5%	3%	4%	5%
<b>GPB Overall</b>									
Activity Level	1,508	11,497	19,546	11,235	10,512	10,437	17,037	42,676	35,079
Corrosion Detected	245	771	1,711	809	648	507	821	1,032	1,370
%Corroded	16%	7%	9%	7%	6%	5%	5%	2%	4%

**GPB Table E.3 External Corrosion Activity and Detection Summary**

In general, the inspection levels over the period 1996 to 2001 remained relatively constant at an average of ~13,000 per year. In 2002 the activity level was increased substantially, targeting 35,000 inspections per year. In 2003 the activity level was slightly over the target of 35,000 inspections. The difference between 2002 and 2003 is the result of ease of access for performing external corrosion inspections. A significant amount of time was spent in the 1Q03 performing off-road inspections, specifically the pipelines over the Kuparuk River and pipelines over tundra without road access from Y Well Pad to P Well Pad. Additionally, activities following the May Y-36 spill and lessons learned directed activities across GPB on equipment with similar configurations as the Y-36 caribou crossing.



**GPB Figure E.1 External Corrosion Activity and Detection Summary**

There was a slight increase in CUI damage detected in 2003 as compared to 2002. Overall, the percentage of locations found with damage has fallen from an initial high of >15% to a field-wide average of 4% in 2003.

### Section E.1.2 Cased Piping Survey Results

In accordance with the agreement with ADEC, 2003 was the final year of a 5-year program to complete a baseline inspection on all cased piping segments. There were approximately 280 segments remaining to complete the 5-year commitment. However, based on the recommendations of the Y-36 Incident Investigation Team, a visual inspection of all cased crossings was completed to identify potential deficiencies similar to Y-36 that may reduce pipeline integrity. As a result of the visual inspections, additional scope was added to the 2003 cased pipe inspection plan to include a total of 492 cased pipe inspections comprising of both baseline and repeat examinations.

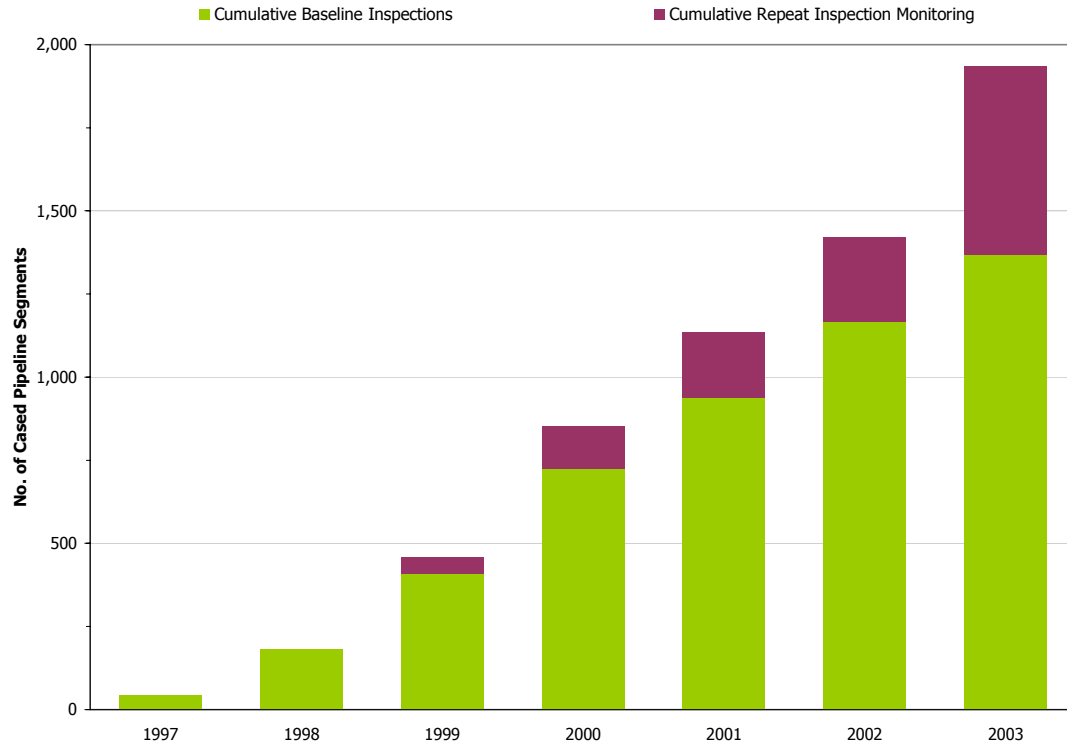
GPB Table E.4 shows the 2003 inspection results for cased pipe segments. Potential metal loss areas are reported as anomalies and severity is semi-quantified as non-relevant (i.e. no metal loss), minor, moderate, or significant.

Service	Technique	Segment	Non-Relevant	Minor	Moderate	Significant	Anomaly Action
3 Phase	E-Pulse	89	63	26	-	-	Proof/Monitor G-Wave
	G-Wave	96	38	20	31	7	Monitor Guided Wave
PW/SW	E-Pulse	21	13	8	-	-	Proof/Monitor G-Wave
	G-Wave	53	23	12	14	4	Monitor Guided Wave
Gas	E-Pulse	86	58	27	1	-	Proof/Monitor G-Wave
	G-Wave	112	55	19	31	7	Monitor Guided Wave
Other	E-Pulse	6	4	2	-	-	Proof/Monitor G-Wave
	G-Wave	2	2	-	-	-	Monitor Guided Wave
PO	E-Pulse	2	1	1	-	-	Proof/Monitor G-Wave
	G-Wave	25	15	6	4	-	Monitor Guided Wave
<b>Total</b>		<b>492</b>	<b>272</b>	<b>121</b>	<b>81</b>	<b>18</b>	

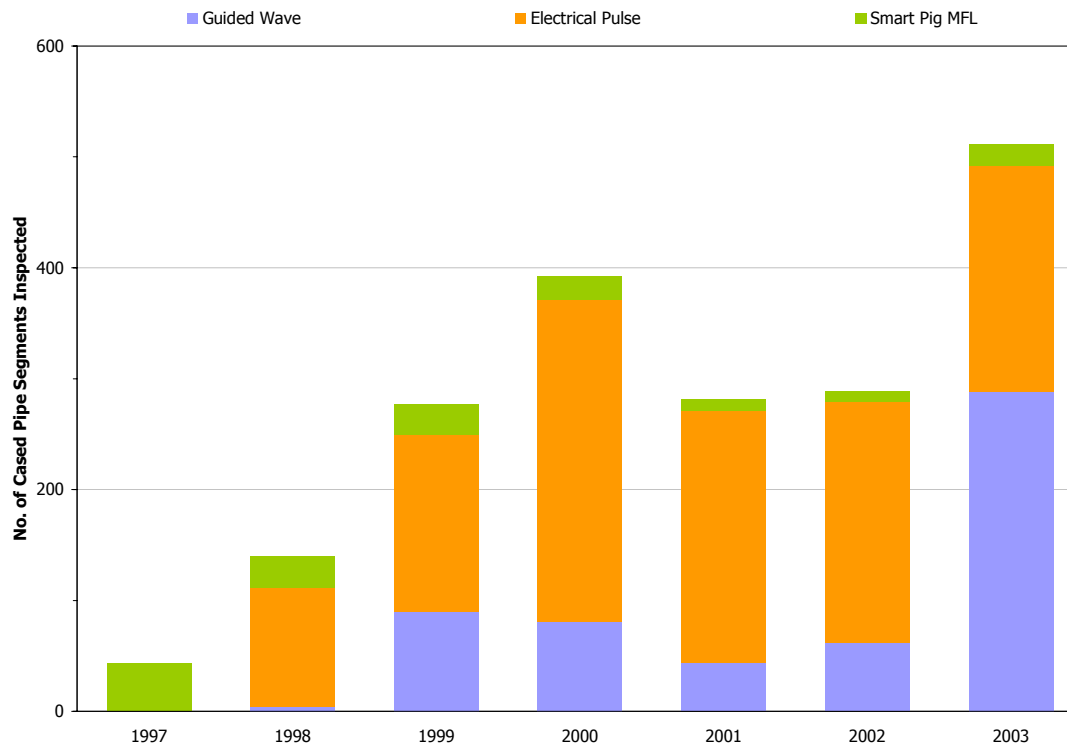
**GPB Table E.4 Cased Pipe Survey Results**

All the potential metal loss anomalies have been prioritized and scheduled for re-inspection based on the reported severity.

GPB Figure E.2, GPB Figure E.3, and GPB Table E.5 show the cased piping inspection activity level over the last 7 years. The activity level has been fairly consistent and includes baseline and monitoring or repeat examinations.



**GPB Figure E.2 Cumulative Cased Pipe Inspection Activity**



**GPB Figure E.3 Cased Piping Inspection History by Detection Method**

<b>Method</b>	<b>1997</b>	<b>1998</b>	<b>1999</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>
Guided Wave	-	4	90	81	44	62	288
Electrical Pulse	-	107	160	290	227	217	204
Smart Pig (MFL)	43	29	27	21	10	10	19
<b>Total</b>	<b>43</b>	<b>140</b>	<b>277</b>	<b>392</b>	<b>281</b>	<b>289</b>	<b>511</b>

**GPB Table E.5 Cumulative Cased Pipe Inspection Activity**

Having completed the initial baseline inspections, a thorough review of cased pipe inspection activity and results has been performed. The intent now is to move the program to the next phase consisting of repeat examinations and monitoring and possibly excavation.

Each of the anomalies identified through the baseline inspection survey from 1997 to 2003 will be prioritized for re-inspection as part of the long-term management of cased pipe segments. Currently the preferred test methodologies will be either guided wave and/or ILI in order to determine the presence of an active corrosion mechanism.

In summary, the cased piping survey activity level has been consistent meeting the commitment to deliver a baseline survey by year-end 2003. The cased piping inventory has been inspected using a number of different techniques including guided wave, electrical pulse, and MFL in-line inspection. The intent now is to move the program to the next phase consisting of repeat examinations and monitoring.

### **Section E.1.3 Excavation History**

There have been 28 cased pipeline segments at road and/or animal crossings excavated over the last 11 years at GPB. Of the 28 excavations, 2 were as a result of loss of pressure containment, the remaining 26 excavations resulted from inspection observations.

In 2003, three crossings (Y-36, X-74, F-74) were partially excavated at the casing end. Three sleeve repairs were installed as a result of external corrosion damage. In addition, a complete cased pipe segment (NGI-14) was replaced by cutting and removing the segment from the casing and installing a new pipe segment.

GPB Table E.8, at the end of this section, shows that of the total 28 segments excavated, 24 were found with external corrosion damage and 4 were found with no external corrosion damage. The identification of potential damage areas through the inspection program and subsequent actions of monitoring and/or excavation, gives confidence that inaccessible pipe segments can be effectively managed to minimize loss as a result corrosion degradation.

### Section E.1.4 External Program Summary

In summary, the level of activity dedicated to external corrosion detection has been relatively constant between 1996 and 2001 at approximately 13,000 locations per year. However, in 2001 it was recognized there was a failure risk that would increase as the field ages. Therefore, the GPB partners agreed to fund an increased level of inspection activity. The activity level for 2003 was considerably greater than historical average at approximately 35,000 inspection locations.

The cased piping program completed the initial base line survey as well as additional inspections resulting from the Y-36 investigation. The program will move into a new phase of repeat inspections, monitoring, and corrective action and repair as warranted.

## Section E.2 Internal inspection

### Section E.2.1 Internal Inspection Program – Scope

This section summarizes the scope and criteria used to determine the frequency of inspection for the internal corrosion inspection program. The over-riding factor in determining inspection intervals is the purpose of inspection based on a combination of equipment condition, corrosion rate, and operating environment. The internal inspection program is sub-divided into four elements, each with a separate purpose and therefore frequency of inspection:

**CRM – Corrosion Rate Monitoring:** The goal of this program is to detect active corrosion in support of corrosion control activities, primarily the chemical inhibition program. The data are complimentary to other monitoring data, such as corrosion probes and corrosion coupons. As the primary aim is to determine when corrosion occurs, this program is of fixed scope at fixed inspection intervals. For a typical cross-country pipeline, the CRM program includes up to 40 inspection locations which include examples of all locations susceptible to corrosion, such as elbows, girth welds, long seam welds, bottom of lines sections, etc. These locations are each inspected twice per year. The inspections are staggered, with half the set being completed in the 1st calendar quarter and half in the 2nd. These are repeated in the 3rd and 4th quarters, respectively. Therefore, information regarding the level of active corrosion (or lack of) in a pipeline is generated every 3 months. The CRM program covers all cross-country pipelines in corrosive service.

**ERM – Erosion Rate Monitoring:** The purpose of this program is similar to the CRM but is aimed at monitoring erosion activity. As this damage mechanism is driven by production variables, i.e. production rates and solids loading, it is driven by 'triggers', such as velocity limits, well work, etc. If such triggers are exceeded, inspections are performed on a

monthly to quarterly basis until confidence is gained that erosion is not occurring.

**FIP – Frequent Inspection Program:** The aim of this program is to manage mechanical integrity at locations where significant corrosion damage is detected. Locations are added to the FIP if they are approaching repair or derate criteria or if unusually high corrosion or erosion rates are detected. As the name implies, inspections are performed frequently until the item is repaired, replaced, derated, taken out of service, or corrosion/erosion rates reduced. The inspection interval varies, depending on how close the location is to repair/derate and the rate of corrosion but does not exceed 1 year. All equipment is covered by the FIP.

**CIP – Comprehensive Integrity Program:** This is an annual program and is aimed at detecting new corrosion mechanisms and new locations of corrosion as well as monitoring damage at known locations. The CIP therefore provides an assessment of the extent of degradation and the fitness-for-service. All equipment is covered by the CIP, although not all equipment is inspected annually.

The scope of the internal inspection program is relatively constant at approximately 60,000 inspection items per year. This includes both field and facility inspections.

### **Section E.2.2 Internal Inspection Program Results**

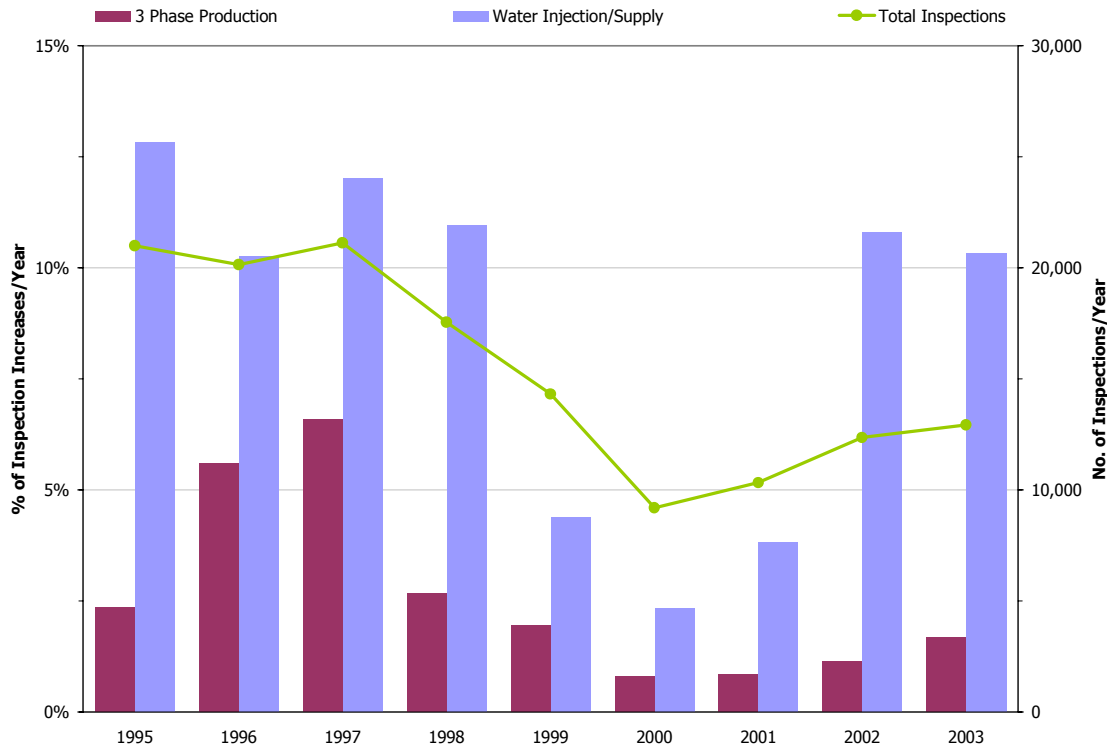
The results presented are aggregate data obtained for all of the above programs for flow lines and well lines. The inspection program results are presented in terms of the number of locations that showed an increase in corrosion damage since the last inspection as a percentage of the total number of repeat inspections,

$$\% \text{ Increases} = \frac{\text{Locations with active corrosion}}{\text{Total \# of reinspected locations}} \times 100$$

The percentage increases is therefore a high level measure of the amount of active corrosion in any given system.

GPB Figure E.4 shows the percentage of inspection increases (%I's) and the number of inspections per year for the flow lines broken out by 3-phase production and water injection (seawater and produced water) service.



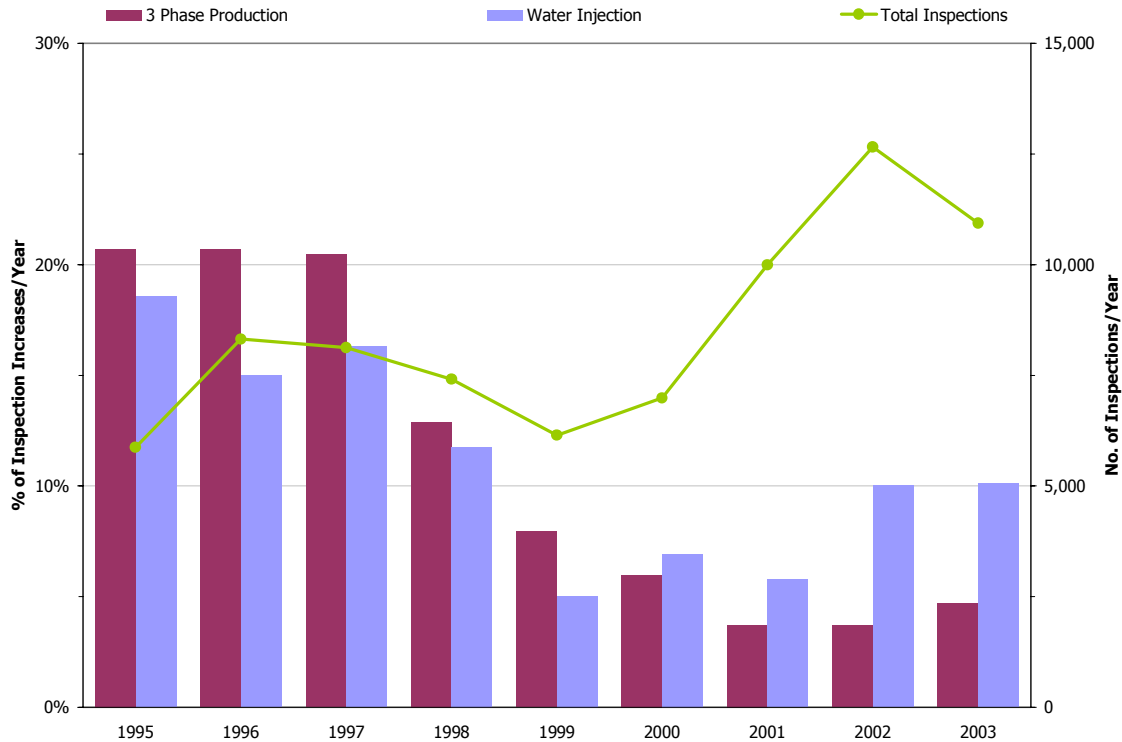


**GPB Figure E.4 Flow Line Internal Inspection Increase by Service**

The percentage of inspection increases in the 3-phase system has declined considerably from 1997 to 2003. However, there was a slight increase in the %I's in 2002 and 2003 on flow lines compared to 2000, which likely reflects the increase in corrosion rates detected in the coupon monitoring program during 2000. Since the inspection program is a lagging indicator of corrosion control, and there is a decline in average WLC corrosion rates realized through the monitoring data, it is expected that the percentage of inspection increases will decrease in the coming year. The delayed response of the inspection program compared with the monitoring program is a result of the longer time base on which this program is typically completed.

The increased corrosion activity in the water injection system reflects the increasing corrosion trends already discussed in the corrosion monitoring section. As noted in Section C.2, there is a strong corrective action plan in place to address the corrosion in the water injection system and the 2003 inspection data suggests some improvement in reversing the negative trend.

GPB Figure E.5 shows the inspection increases trend and the number of inspections per year for the well lines.



**GPB Figure E.5 Well Line Internal Inspection Increase by Service**

For the 3-phase well lines in the long term, there is a decrease in corrosion activity as measured by the percentage of inspection increases. This is the same trend as seen in the flow lines. In the short term, the slight increase in corrosion activity seen in the flow lines is similarly reflected in the well line data.

For the water system, corrosion activity is seen to be declining from 1995 through 2001. However, as with the flow lines, there has been a recent increase in activity in the well line data.

In summary, the long-term trends for the 3-phase production system are very similar for both the flow lines and the well lines. In each case the level of corrosion activity has dropped dramatically from the mid-1990's to the levels that have been seen in recent years. In the water systems, again, there is significant correlation between the trends in the flow lines and those in the well lines. In each case, the level of corrosion activity has fallen from the mid-1990's through 2000/2001. However, since 2001 there has been a marked increase in the level of corrosion activity, which has been discussed in detail in Section C.

### **Section E.3 Fitness for Service Assessment**

The basic fitness-for-service criterion used by BPXA is ANSI/ASME B31G. The base document is the modified B31G, PRC 3-805, which is augmented with

additional requirements defined in BP specification SPC-PP-00090, "Evaluation and Repair of Corroded Piping Systems".

Application of fitness-for-service is best illustrated by the following example and discussion using a typical 24" diameter, 375-mil wall thickness cross-country low-pressure (LP) flow line. The average depth of damage for this example is approximately 24% or 90 mils and average corrosion network length of 8.9". In calculating the corrosion rate to achieve this depth of damage, it was assumed that the corrosion rate is linear since the beginning of field life in 1977.

GPB Figure E.6 summarizes the dependence of Maximum Allowable Operating Pressure (MAOP) with the remaining wall thickness of a section of flow line based on ANSI/ASME B31G and is intended to show the multiple-layers of protection to the environment provided by the current fitness-for-service criteria. At the original wall thickness of 375 mils, the example flow line has a B31G calculated MAOP of ~1400 psi. As the wall thickness is reduced by corrosion, this pressure containment capacity is also reduced.

GPB Table E.6 shows the MAOP for various wall thicknesses starting from the original wall thickness of 375 mils. It can be seen that the repair criterion used provide a significant level of conservatism over the minimum wall thickness required to retain the maximum operating pressure. In addition, high-level over-pressure protection provides additional protection over the normal operating pressure.

In addition to the depth of damage discussed, there are a number of other considerations that have to be accounted for when assessing fitness-for-service. Some of the concerns are,

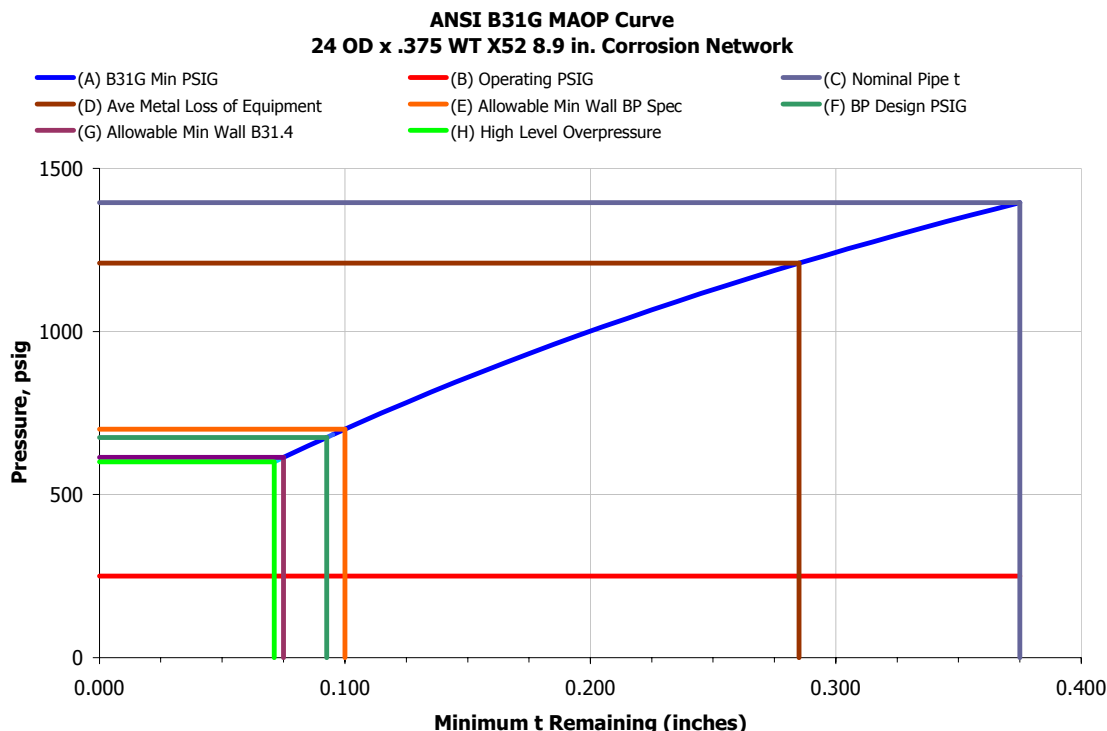
**Localized/Pitting Corrosion** Localized/pitting corrosion consisting of clearly defined relatively isolated regions of metal loss. The axial and circumferential extent of such regions needs to be determined and any potential areas of interaction where there is axial overlap between pitting regions.

**General/Uniform Corrosion** General corrosion consisting of widespread corrosion between islands of original material, again, as with pitting corrosion, the axial and circumferential extent of such regions need to be determined. The extent of damage is determined by the boundaries of good or non-corroded material surrounding the damaged area.

**Interaction** If more than one areas of metal loss exist in close proximity, the possible interaction between these corroded areas needs to be considered. The worst case for interaction of several corroded areas is that a composite of all the profiles within a given metal-loss area needs to be considered.

**Critical Dimensions** The critical dimensions of metal loss, whether internal or external corrosion damage, need to be determined depending on the corrosion damage morphology described above. The most important dimensions being, the axial or longitudinal length, and the maximum depth of damage.

**Evaluation of Corroded Pipe** The evaluation of corroded pipe involves determining the remaining strength and safe operating pressure on the basis of the overall axial length, circumferential extent, and maximum depth of the corroded area.



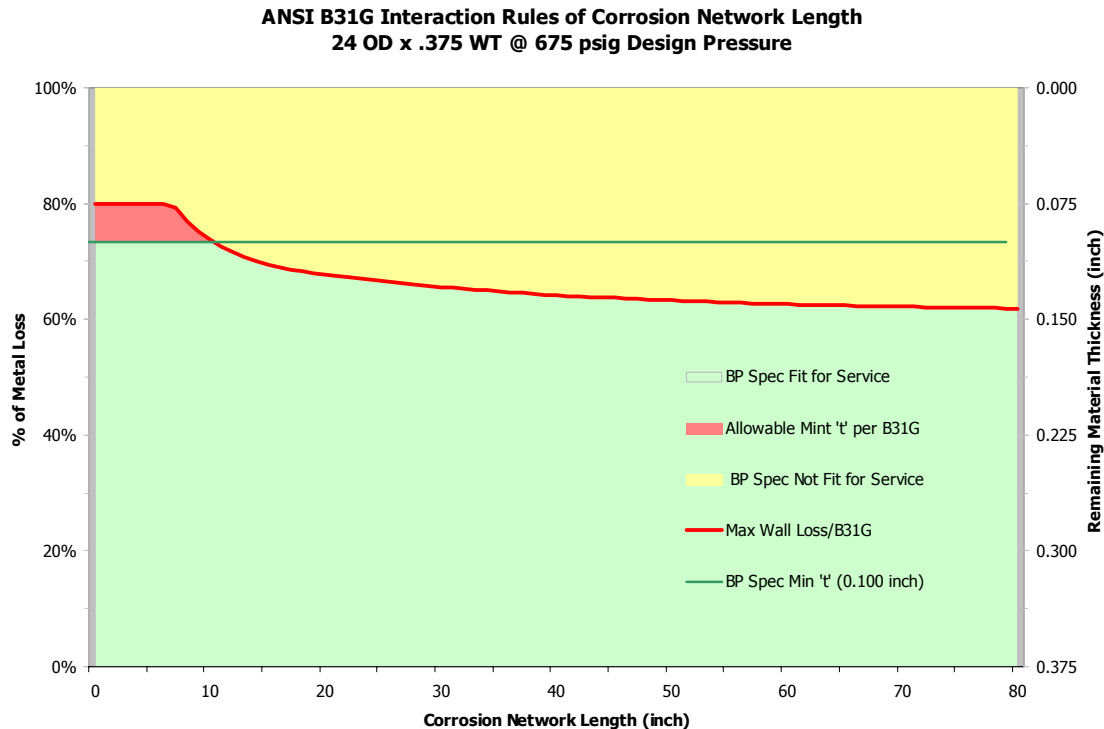
Legend		Description/Comments
(A)	B31G Min PSIG	The relationship between maximum allowable operating pressure, MAOP, as given by B31G and the remaining wall thickness
(B)	Operating PSIG	The normal operating pressure for a typical low pressure common line or flow line (CL/LDF)
(C)	Nominal Pipe t	The original nominal pipe wall thickness which for this example is 0.375" (375 mils) as is the case for many of the flow lines at GPB
(D)	Ave metal loss	From the inspection data an average pit depth or depth of damage across the field for the 24" LP OIL flow lines
(E)	Min Wall BP Spec	The minimum wall thickness, 0.100", which is permitted under BP specification SPC-PP-00090 for the management of corroded pipe-work. Any location at or below this level is actioned regardless of the calculated MAOP
(F)	BPXA Design PSIG	The original design pressure that the pipe wall thickness was designed to retain
(G)	Allowable Min Wall	Allowable minimum wall thickness under B31 below which a repair is mandated by code
(H)	High level P protection	High level over-pressure protection for the LP systems as either a pressure switch or the PSV's on the separator/slug-catcher

**GPB Figure E.6 MAOP versus Remaining Wall Thickness**

Step	t, mils	MAOP	Curve	Description
1	375	1395	(C)	As constructed pipe condition with no corrosion or degradation of wall thickness
2	285	1209	(D)	After 25+ years of service the average wall loss for the flow line system is 24% or 90 mils and has a MAOP of 1209 psi. This is an equivalent corrosion rate of ~4 mpy. At the average corrosion rate seen to date, in approximately 50 years the wall loss will be such that it reaches the repair criteria in Step 3. Note that the target corrosion rate is 2 mpy to provide additional protection and scope for extended field life.
3	100	700	(E)	The BP repair criterion from BP Specification SPC-PP-00090 is 100 mils with an MAOP of 700 psi. This repair criterion is 25 psi above the design pressure and 25 mils or 33% above minimum wall thickness defined by code B31G giving significant level of additional protection
4	95	675	(F)	The original system design pressure
5	75	614	(G)	The minimum wall thickness allowed under B31G for this application which is 80% wall loss regardless of pressure
6	71	600	(H)	High level over-pressure protection for the low pressure production system at Greater Prudhoe Bay
7		250	(B)	The normal operating pressure for the system

GPB Table E.6 Thickness, MAOP Correlation

GPB Figure E.7 illustrates the FFS envelop for a combination of depth and length of defect as defined in BP Specification SPC-PP-00090. As can be seen from the curve, the criteria for allowable operating service condition is more conservative than the industry standard at the low end of the remaining wall thickness. This conservatism reflects two issues, (a) the need to provide a margin for error in the determination of wall thickness and corrosion rate, and hence remaining life, and (b) the decreased accuracy of the NDE techniques in use at a wall thickness of less 100 mils.



**GPB Figure E.7 Fitness-for-Service Envelope Based on BP SPC-PP-00090**

In addition, repairs are typically scheduled when the corrosion damage has reached 105% of the repair criteria. This additional conservatism is in order to allow repairs to be planned rather than requiring an immediate plant shutdown.

In summary, the current equipment FFS assessment for piping accounts for two major elements,

- Remaining strength of material is sufficient to contain internal pressure as calculated by ANSI/ASME B31G/modified B31G methodology,

and

- Minimum thickness, regardless of pressure retaining calculation, is equal to the greater of 0.100 inch or 20% remaining wall thickness

whichever is the greater remaining wall thickness of the two assessment criteria. These same criteria are applied to remaining flow and well lines with the appropriate characteristics and parameters.

## Section E.4 Correlation Between Inspection and Corrosion Monitoring<sup>7</sup>

As noted in GPB Table B.12, inspection and corrosion monitoring have different characteristics; in particular, inspection techniques are comparatively insensitive but are the most accurate as they measure actual wall loss. In contrast, corrosion monitoring is more sensitive but less accurate as a measure of corrosion rate as the weight loss coupon is not an integral part of the pipe wall.

Therefore, in order to have good confidence in the results from the corrosion-monitoring program, it is necessary to show a correlation between the chosen monitoring program and the results of the inspection program. The following section describes the correlation between inspection and monitoring programs for the 3-phase production system.

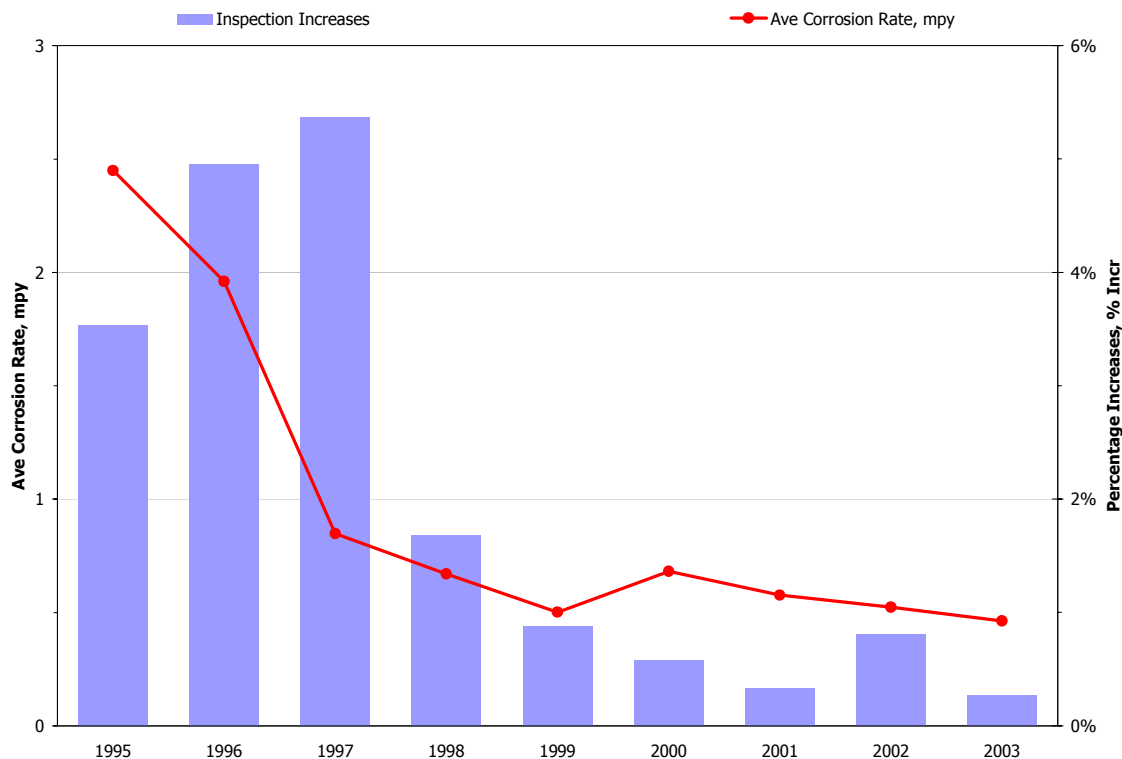
GPB Figure E.8 shows a similar decreasing trend in average corrosion rate from WLC and the percentage of increases found in the inspection program for the 3-phase well line and flow line. It should be noted that the inspection results included in the analysis are not the full data set but has been refined to include only that data which has an inspection interval (time since last inspection) of less than 730 days (two years). Also, the indicated reporting year has been changed to reflect the mid-point of the inspection interval rather than the time of inspection as in the other figures in this report. This change in the reporting time compensates for the fact that corrosion is occurring over the entire time interval between inspections. Similarly, the weight loss coupon corrosion rates are reported as the mid-point of the exposure period not the removal date.

From the correlation between inspection and corrosion monitoring, a number of important conclusions can be drawn,

- As the corrosion rates decrease as a result of the effectiveness of the inhibition program, then further program optimization will be driven by the information gained from the corrosion monitoring program rather than the inspection program
- Timely optimization of the chemical program can not be reliant on feedback from the inspection data but must be managed through the corrosion monitoring program
- Because of the lower sensitivity of the techniques used in the inspection program, the corrosion rates in the 3-phase flow lines are below the detection limits for inspection; therefore corrosion rate monitoring becomes a function of the coupon program leaving inspection as a confirmation and integrity assessment tool

---

<sup>7</sup> In addition to Charter Work Plan, this information supplied to provide additional context and help in understanding BPXA's corrosion management activities



**GPB Figure E.8 Correlation of Corrosion Rate and %Increases, 3-phase Production**

A similar degree of correlation exists between the corrosion monitoring and the inspection data for the water injection systems. GPB Figure E.4 and GPB Figure E.5 show increasing corrosion activity in both the flow lines and well lines for the water system, which is also reflected in the corrosion monitoring data depicted in GPB Figure C.15 and GPB Figure C.16.

In summary, the data in this section clearly shows that corrosion rates as determined by both inspection and corrosion-monitoring techniques are falling and that the corrosion management plan for internal corrosion in 3-phase production service is effective. Furthermore, the correlation between the inspection data and the corrosion monitoring data allows the corrosion monitoring data to be used with confidence to manage the chemical treatment program in a timelier manner.

### **Section E.5 In-line Inspection**

In-line inspection (ILI) tools, or smart pigs, are used at GPB where pigging facilities and process environment allow for technical and cost effective performance within the capabilities of the instruments. Magnetic flux leakage (MFL) type tools are the most commonly used by BPXA.

It is important to note that because the vast majority of the cross-country flow lines are above ground, the value of ILI data are considerably lessened



compared to buried or underground systems. The primary value for GPB is in the initial identification and location of damaged locations within a pipeline system. Having initially identified the location of damaged areas, the long-term integrity, pipeline condition and current corrosion rate, of the flow line can be more effectively managed through the use of targeted manual NDE techniques.

Having established the condition and location of damaged sections of line the locations are then added to the routine NDE program where the condition and fitness-for-service is determined and where the on-going corrosion rate and level of corrosion mitigation can be monitored.

There are limitations with the ILI technology currently used at GPB. A typical high resolution<sup>8</sup> MFL smart pig gives wall thickness measurements that are  $\pm 10\%$  of the nominal wall thickness and sizing resolution of 3 times wall thickness for length and width assessment. In addition, there are temperature and pressure limitations that prevent or make difficult the use of MFL tools in many lines at GPB. The typical upper operating temperature for the MFL tools is 122°F/50°C compared with a typical separator fluids temperature of 150-160°F/65-71°C.

While the ILI program is an important element in the overall corrosion and integrity management program, it should be considered like any other inspection or monitoring technique as simply another tool to be applied where it delivers the most value.

When used, smart pig inspections are performed to gain a relative understanding of pipeline condition and rate of deterioration and/or to provide confidence that the internal and external conventional inspection programs have identified locations where mechanical integrity is at risk. Because MFL tools do not directly measure pipeline condition, results from in-line inspections are not reported in as received from the smart pig service company but are reported as part of the overall NDE summary.

Areas identified by ILI and interpreted as being a risk to future operation of equipment, are verified through visual, radiographic and/or ultrasonic inspection techniques and the results are reported as part of routine inspection programs.

In 2003, three 3-phase production flow lines were examined by smart pig (MFL) inspection. One of these lines, PTMCLS01/02, had not previously been subject to ILI, the other two, S-36 and Y-36, were last smart pigged in 1997. GPB Table E.7 summarizes equipment service, diameter, and length.

---

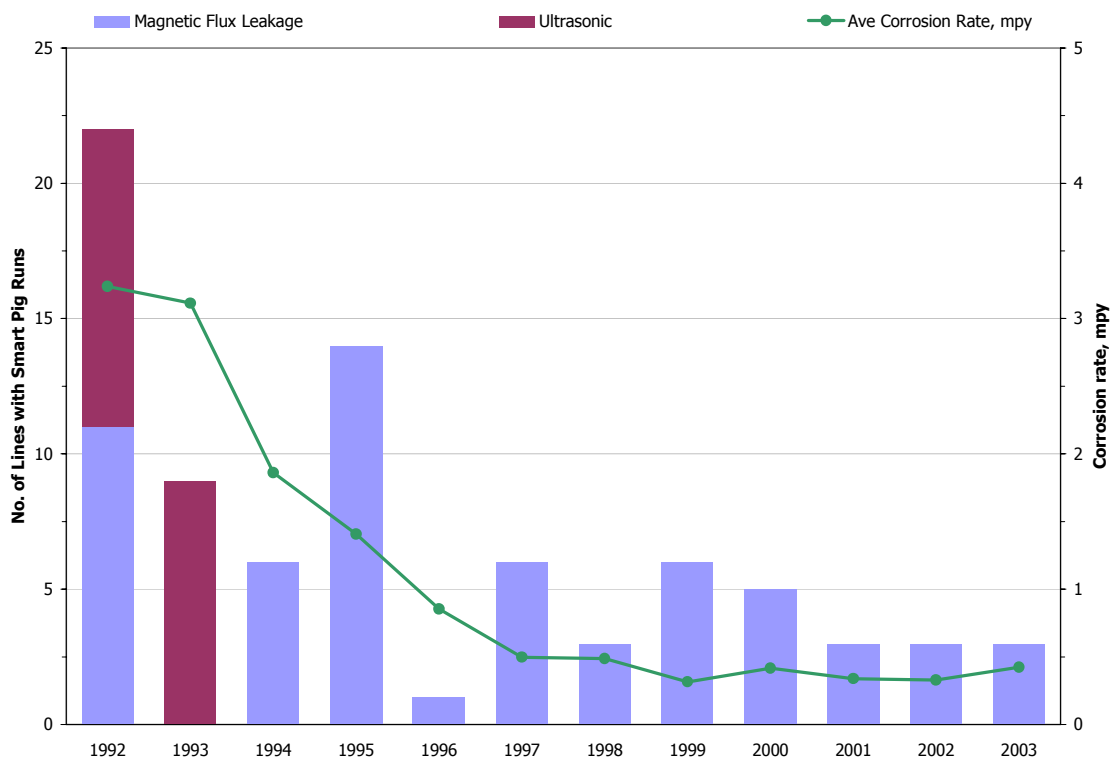
<sup>8</sup> MFL manufacturer technical data sheet

Equipment	Service	Diameter	From	To	Length (ft)
PTMCLS01/02	3 Phase	24"	Drill Site LS01	LPC	25,725
S-36	3 Phase	24"	S Pad	GC2	32,444
Y-36	3 Phase	24"	Y Pad	GC1	33,478

**GPB Table E.7 Completed Smart Pig Assessments**

Metal loss features reported in each of the lines smart pigged have been prioritized for verification by radiographic and/or ultrasonic inspection. The verification results through 2003 are included in the aggregate inspection data. As a result of the verification process in 2003, two (2) repairs were identified resulting from external corrosion degradation. Additional follow-up of the reported features is an ongoing part of the normal radiographic and ultrasonic NDE activity at GPB.

GPB Figure E.9 shows the ILI activity level from 1992 through 2003. The level of activity has fallen from a high of 25 in-line inspections per year in 1992 to 3 inspections completed in 2003. In addition to the ILI activity level, the chart also shows the average corrosion rate for the oil service flow lines.



**GPB Figure E.9 Historical Smart Pig Activity and Corrosion Rate**

The reduction in ILI activity level coincides with the decline in corrosion rate and reflects the change in emphasis of the program. As the corrosion rates have fallen, the immediate concern of the program has shifted from the short-term integrity of the flow line, which is focused on condition, to the long-term integrity of the flow line, which has a dual focus of remaining wall thickness and corrosion rate. This long-term integrity is better managed through higher resolution methods such as corrosion monitoring and manual radiographic and ultrasonic NDE.

In summary, while ILI is an important tool to have available for the management of the long-term integrity of the flow lines, it is not always the most appropriate or applicable for GPB because of the operating conditions, design and accessibility of the pipelines to precision manual methods of NDE. However, ILI will likely continue to be used to assist and compliment the overall program.

## **Section E.6 Inspection Summary**

In summary, the main conclusions from the inspection section are,

- The external corrosion inspection program, at >35,000 items, for 2003 was above the target. Approximately 4% of these inspections showed damage, which is consistent with the overall average in recent years.
- The cased piping survey completed a base line inspection on all pipeline segments as agreed with ADEC and the program is continuing to evolve into a process of monitoring and corrective action.
- A unified internal inspection philosophy and program structure has been implemented across GPB with a total program size of approximately 60,000 items.
- The inspection results for both the flow line and well line 3-phase systems show improved performance in the long term. In the short term there is a slight increase in the corrosion activity. This is expected to be reversed following the trend seen in the corrosion coupon program as a result of the better performance of the corrosion inhibitor.
- The water injection systems show a long term improving trend. However, there is an increase in the corrosion activity in the short term and, as discussed in Section C.2, corrective actions have been put in place in the sea water system and additional inhibition has been added in 2002 to the produced water system.
- The inspection interval and fitness-for-service criteria, as defined by B31G, were discussed in the context of the current piping corrosion rate and piping condition.
- The results of the inspection program and the weight loss coupon program from the 3-phase oil service were shown to be strongly correlated. The reduction in corrosion activity from both measures being

attributable to the implementation of an aggressive and increasing corrosion inhibition program in the 3-phase flow lines since 1995.

- A similar level of correlation was seen in the water injection system information for both inspection and corrosion monitoring.

<b>Year</b>	<b>Cased Pipe Location</b>	<b>Equipment Excavated</b>	<b>Observation</b>	<b>Corrective Action</b>
1992	COTU Access Road	FS1 to FS2 12" MI Distribution	10% external wall loss	Insulation/coating/tape repair
1995	S Pad West Entrance Crossing	S Pad 24" 3 Phase Production	61% external wall loss	Sleeve/insulation/coat repair
		S Pad 14" Produced Water	36% int/ext wall loss	Sleeve/insulation/coat repair
		S Pad 10" Gas Lift	34% external Wall Loss	Insulation/coating repair
		S Pad 8" Miscible Injection	41% external wall loss	Replaced segment/FBE
	GC1 Main Entrance	Distribution 24" Gas Lift	29% external wall loss	Insulation/coating repair
		Y Pad 24" 3 Phase Production	24% external wall loss	Insulation/coating repair
	GC2 to GC1 Caribou Crossing	Distribution 24" Gas Lift	42% external wall loss	Sleeve/insulation/coat repair
		Y Pad 24" 3 Phase Production	26% external wall loss	Insulation/coating repair
1996	GC-1 Spine Road	Distribution 24" Gas Lift	53% external wall loss	Sleeve/insulation/coat repair
		D Pad 24" 3 Phase Production	33% external wall loss	Insulation/coating repair
		Y Pad 24" 3 Phase Production	18% external wall loss	Insulation/coating repair
		Distribution 20" Produced Water	8% external wall loss	Insulation/coating repair
	E Pad Entrance	E Pad 24" 3 Phase Production	21% external wall loss	Insulation/coating repair
	GC3 to FS3 Caribou Crossing	Distribution 24" Gas Lift	No corrosion damage	None
	FS1 to FS2 Caribou Crossing	Distribution Natural Gas 30"	11% external wall loss	Insulation/coating/tape repair
		Sales Oil 30"	14% external wall loss	Insulation/coating/tape repair
		Distribution 24" Gas Lift	No corrosion damage	None
		Distribution 32" Sea Water	No corrosion damage	None

**GPB Table E.8 Cased Piping Excavation History**

This page is intentionally blank

<b>Year</b>	<b>Cased Pipe Location</b>	<b>Equipment Excavated</b>	<b>Observation</b>	<b>Corrective Action</b>
1998	S Pad East Entrance Crossing	S Pad 10" Gas Lift	~80% wall loss - ext rupture	Replaced segment
	GC2 to GC1 Caribou Crossing	Distribution 24" Gas Lift	9% external wall loss	Insulation/coating repair
	GC2 to GC1 Q Pad Rd Crossing	Distribution 34" Natural Gas	No corrosion damage	Insulation/FBE coated
2000	S Pad East Entrance Crossing	S Pad 24" 3 Phase Production S Pad 14" Produced Water S Pad 8" Miscible Injection	~60% external wall loss ~50% external wall loss 25% external wall loss	Replaced segment/coat repair Replaced segment/coat repair Sleeve/insulation/coat repair
	GC2 to GC1 Caribou Crossing	Y Pad 24" 3 Phase Production	Leak -external corrosion	Partial excavation/sleeve repair
	X Pad Pipeline Access Rd Crossing	X Pad 24" 3 Phase Production	~75% external wall loss	Partial excavation/sleeve repair
2003	F Pad Pipeline Access Rd Crossing	F Pad 24" 3 Phase Production	24% external wall loss	Partial excavation/none
	NGI Pad Road Crossing	NGI Pad 14" Gas Cap Injection	58% external wall loss	Replaced segment

**GPB Table E.8 (Continued) Cased Piping Excavation History**

This page is intentionally blank



## **Section F**

### **Repair Activities**





## Section F Repair Activities

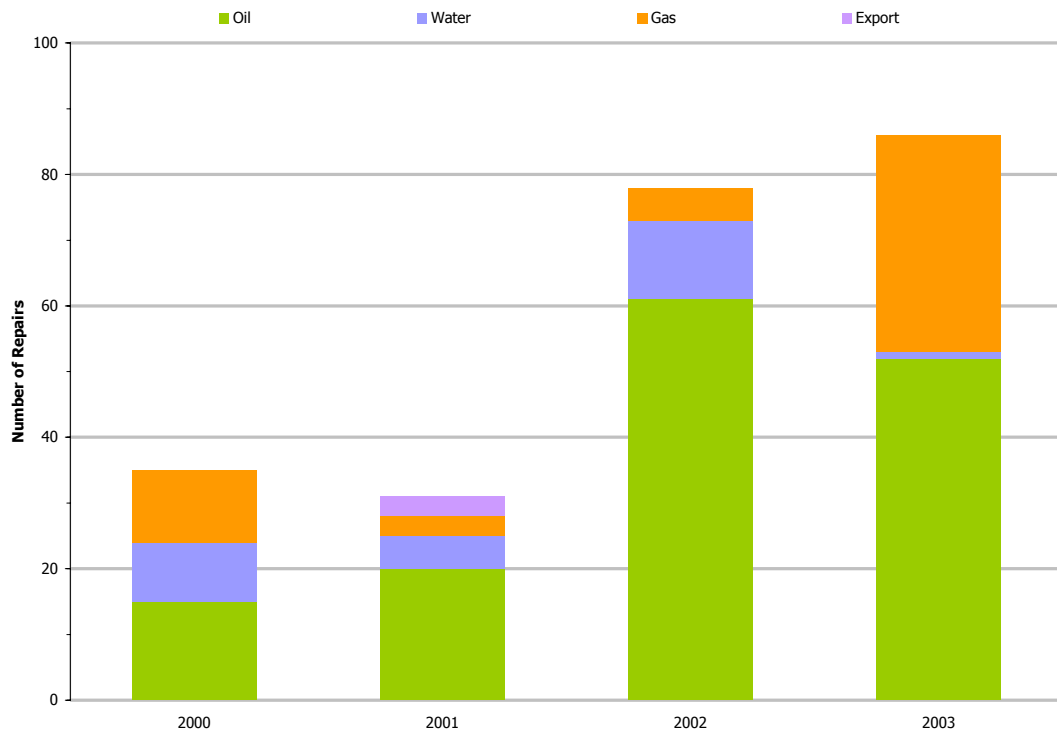
The repair activities shown in GPB Table F.1 include a total of 86 repairs as compared to 78 in year 2002. GPB Figure F.1, GPB Figure F.2, GPB Figure F.3, and GPB Table F.2, show the 4-year trend in repairs grouped by service, damage mechanism, and equipment, respectively.

<b>Service</b>	<b>Type</b>	<b>Internal</b>	<b>External</b>	<b>Mechanical</b>	<b>Total</b>
Oil	FL	-	28	1	29
	WL	3	20	-	23
PW	FL	-	-	-	-
	WL	-	1	-	1
SW	FL	-	-	-	-
	WL	-	-	-	-
Gas	FL	-	23	1	24
	WL	-	8	1	9
Total		3	80	3	86

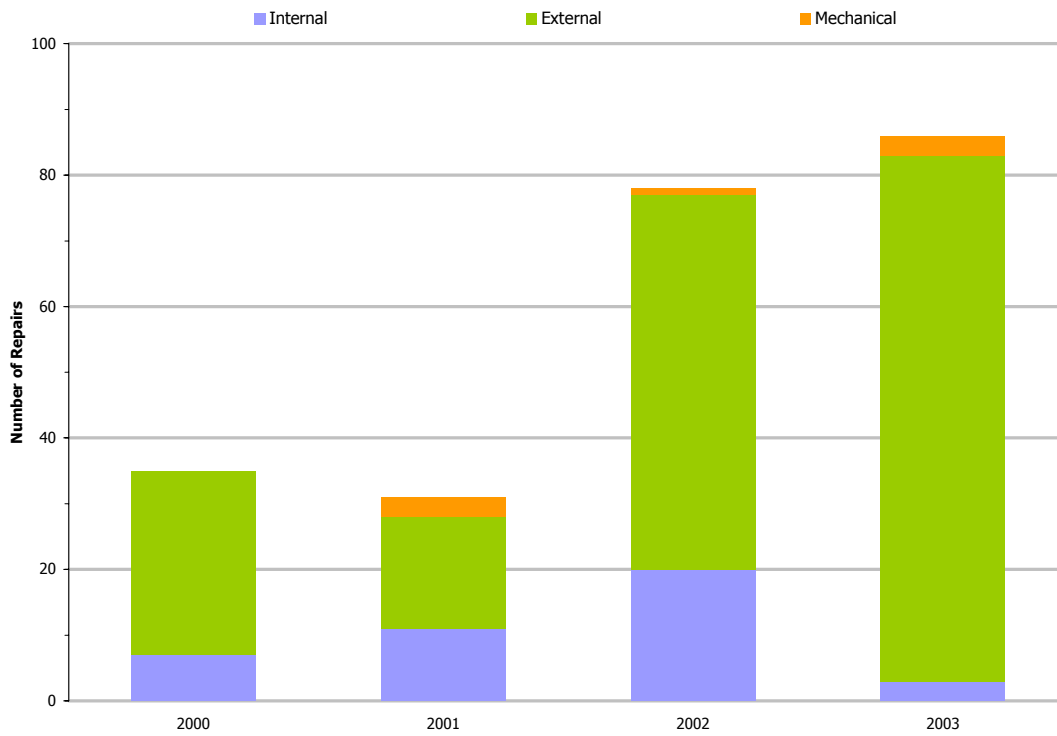
**GPB Table F.1 2003 Repair Activity**

Of the 86 repairs, 80 were associated with external corrosion and reflect the continued emphasis on external corrosion inspection. All three (3) internal corrosion related repairs were on well lines.

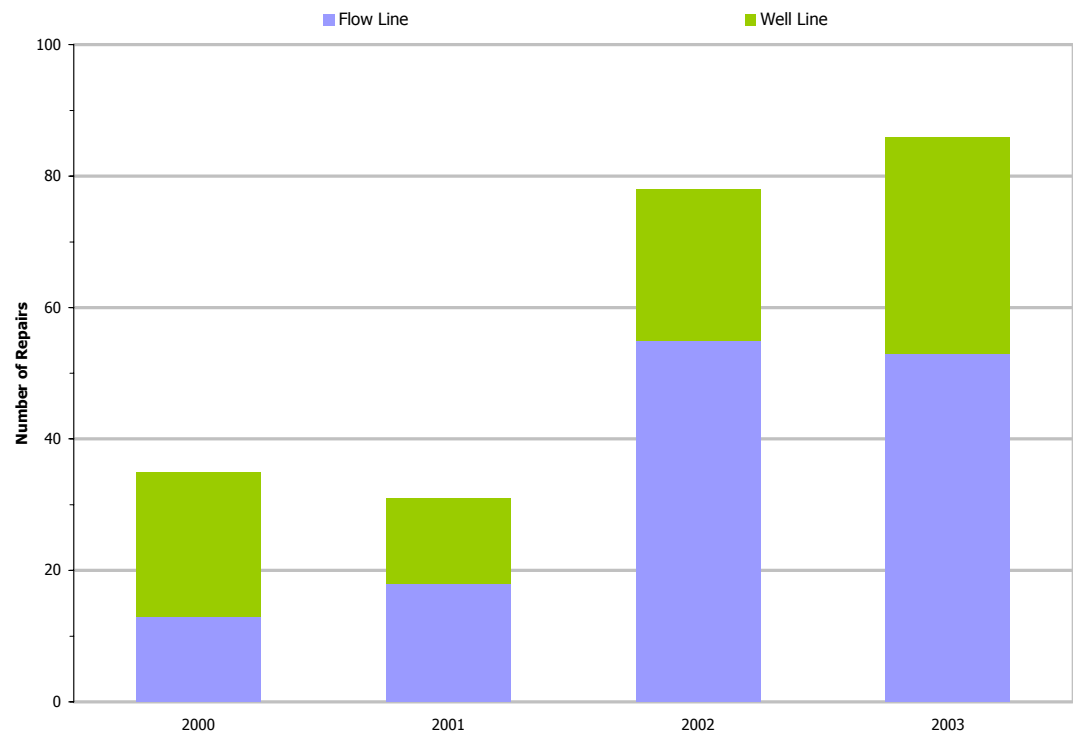
## Part 1 – Greater Prudhoe Bay Performance Unit



**GPB Figure F.1 Repairs by Service**



**GPB Figure F.2 Repairs by Damage Mechanism**



**GPB Figure F.3 Repairs by Equipment**

In summary, there was a small increase in the number of repairs in 2003 compared to 2002, 78 and 88 respectively. External repairs dominate the level of repair activity, which reflects the continued emphasis on the external corrosion program.



	Oil		Water		Gas		PO	Total
	Flow Line	Well Line	Flow Line	Well Line	Flow Line	Well Line	Flow Line	
<b>2000</b>								
Internal	2	5	-	-	-	-	-	7
External	1	7	2	7	8	3	-	28
Mechanical	-	-	-	-	-	-	-	0
Total	3	12	2	7	8	3	0	35
<b>2001</b>								
Internal	2	4	1	1	-	-	3	11
External	7	5	3	-	2	-	-	17
Mechanical	-	2	-	-	-	1	-	3
Total	9	11	4	1	2	1	3	31
<b>2002</b>								
Internal	8	7	1	4	-	-	-	20
External	35	11	6	1	4	-	-	57
Mechanical	-	-	-	-	1	-	-	1
Total	43	18	7	5	5	0	0	78
<b>2003</b>								
Internal	-	3	-	-	-	-	-	3
External	28	20	-	1	23	8	-	80
Mechanical	1	-	-	-	1	1	-	3
Total	29	23	0	1	24	9	0	86
<b>Grand Total</b>	<b>84</b>	<b>64</b>	<b>13</b>	<b>14</b>	<b>39</b>	<b>13</b>	<b>3</b>	<b>230</b>

GPB Table F.2 Historical Repairs by Service

This page is intentionally blank



## **Section G**

### **Corrosion and Structural Related Spills and Incidents**





## Section G Corrosion and Structural Related Spills and Incidents

### Section G.1 Corrosion Related Leaks

This section summarizes the corrosion and structural related incidents that occurred in 2003 and provides a historical perspective on the leaks (loss of containment) and saves (repairs before leak of non-FFS equipment).

GPB Table G.1 summarizes the equipment, failure mechanism and volume of leaks due to corrosion that occurred in 2003. Of the 2 leaks that occurred in 2003, 1 was associated with external corrosion and 1 with cyclic fatigue cracking.

Service	Location	Type	Date	Mechanism	Volume
3-phase production	Y-36	FL Caribou X-ing	26-May-03	CUI	Oil - 1,325 gal. PW – 4,986 gal
Gas	W/Z-804	FL	08-Dec-03	Mech	NGL - 0.5 gal

	Surface		Service				Mechanism			
	Int	Ext	OIL	SW	PW	Gas	CO <sub>2</sub>	Erosion	CUI	Mech
WL										
FL		2	1			1			1	1

**GPB Table G.1 2003 Leaks Due to Corrosion/Erosion**

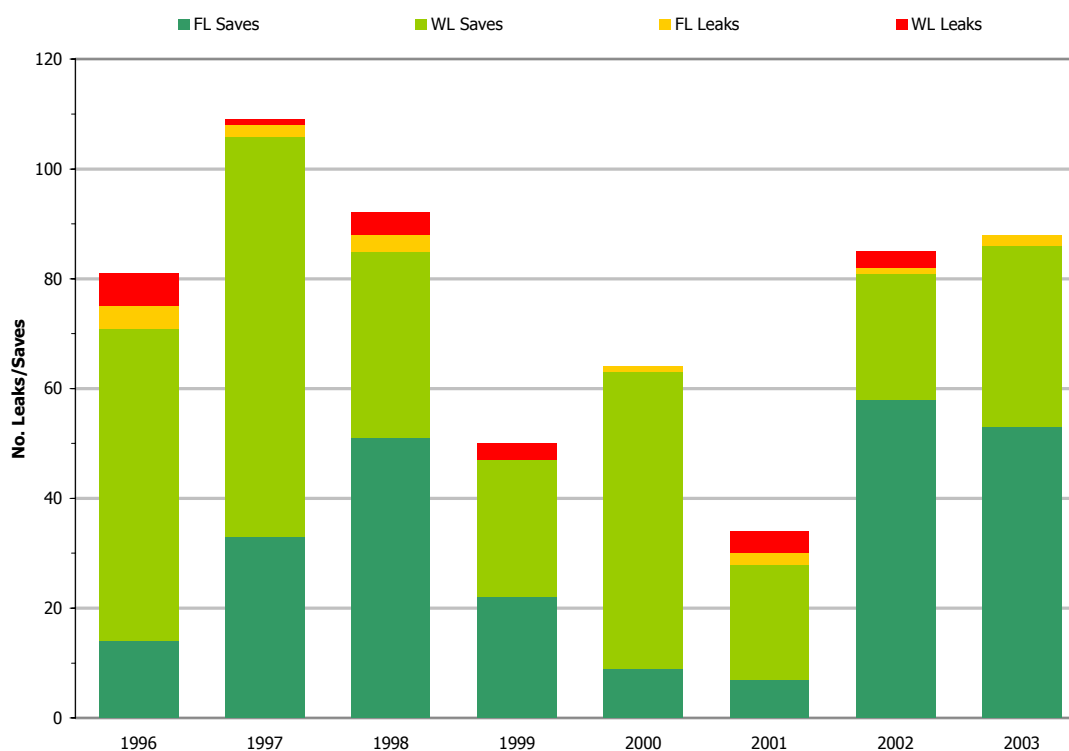
GPB Table G.2, GPB Figure G.1 and GPB Figure G.2 show the number of corrosion related leaks and saves from 1996 through 2003. The ratio of leaks to saves provides a high level measure of the performance of the inspection program at detecting severe damage before it results in a failure. A 'save' is defined as a location found via the inspection program that warrants a repair, system derate, replacement or removal from service as the equipment no longer meets the FFS criteria defined in Section E.3. It should be noted that items are typically scheduled for repair at 105% of design pressure, to allow time to schedule and complete the repair before the item requires removal from service.

The significant increase in number of saves is a direct result of the ramp-up of the external inspection program.

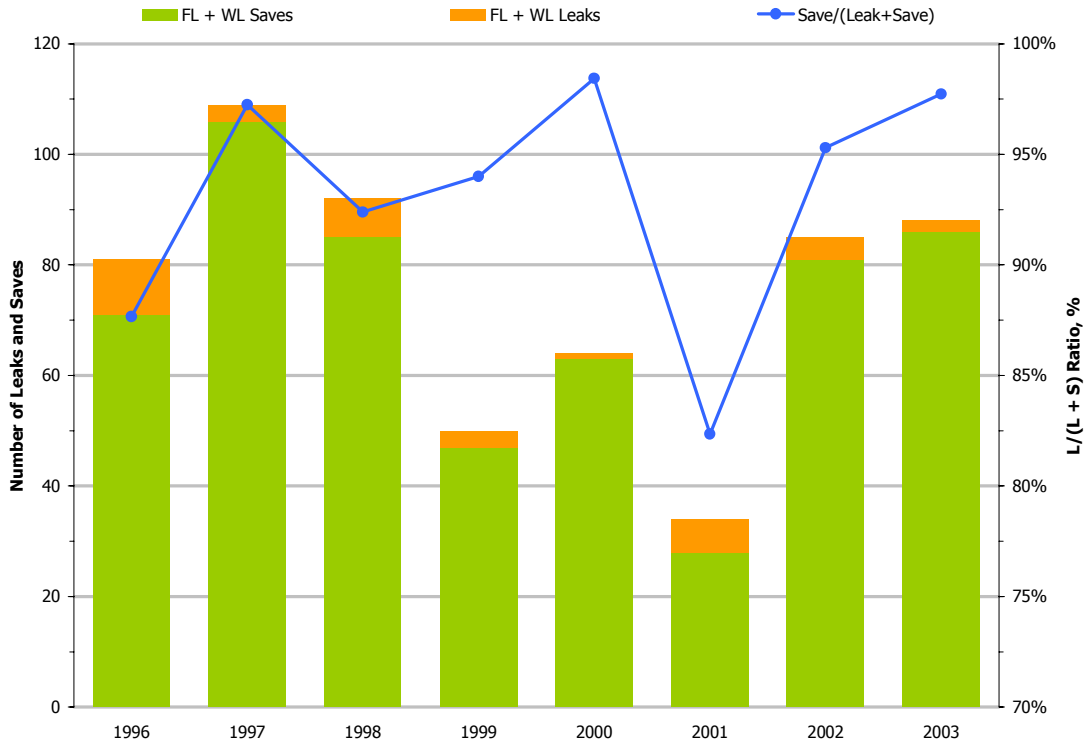
Part 1 – Greater Prudhoe Bay Performance Unit

	Flow Lines			Well Lines			Total
	Saves	Leaks	$\frac{S}{(L + S)} \%$	Saves	Leaks	$\frac{S}{(L + S)} \%$	$\frac{S}{(L + S)} \%$
1996	14	4	78%	57	6	90%	88%
1997	33	2	94%	73	1	99%	97%
1998	51	3	94%	34	4	89%	92%
1999	22	0	100%	25	3	89%	94%
2000	9	1	90%	54	0	98%	97%
2001	7	2	78%	21	4	84%	82%
2002	58	1	98%	23	3	89%	95%
2003	53	2	96%	33	0	100%	98%

**GPB Table G.2 Historical Corrosion Leaks and Saves**



**GPB Figure G.1 Historical Corrosion Leaks and Saves by Line Type**



GPB Figure G.2 Historical Corrosion Leaks and Saves

## Section G.2 Structural Integrity Issues

Structural integrity issues are related to damage caused by structural movement: subsidence, jacking, cyclic fatigue, impact, slugging, snow loading, etc. There are several activities designed to observe and report these structural issues.

### Section G.2.1 Waking Speed Survey

Where there is perambulatory access, a Walking Speed Survey (WSS) is performed. The WSS consists of a visual examination of process equipment and system components to identify mechanical integrity deficiencies. Anomalies are noted and evaluated by the Field Mechanical Piping Engineer for action as appropriate.

As the name implies the observations are made at 'walking speed' and are focused on, but not limited to,

- Piping and insulation
- Structural components
- Electrical equipment
- Instrumentation equipment
- Communication equipment

- Chemical injection tubing
- Pipe line road and animal crossings

WSS is a 5-year recurring program with the following schedule,

Year	Scheduled	Completed	Equipment Description
1	2002	✓	GPB East Cross Country Pipelines
2	2003	✓	GPB West Cross Country Pipelines
3	2004		GPB East Well Pads
4	2005		GPB West Well Pads
5	2006		Lisburne Cross Country Pipelines/Drill Sites

**GPB Table G.3 Structural/Walking Speed Survey Schedule**

A WSS of the GPB west flow lines was completed in 2003.

### **Section G.2.2 Routine Surveillance**

Field Operations and Security personnel are tasked as the primary identifiers of flow lines and well lines with potential structural integrity anomalies. Observations of wind-induced vibration, excessive pipe movement, out-of-place pipe guides, bent piping, etc. are reported.

An analysis of potential integrity anomaly is completed by a competent engineer to determine any required action. Additional analysis may be required by the Field Mechanical Piping Engineer or third party engineering experts.

For example, if excessive sagging between pipeline supports is observed, the engineer requests an NDE inspection of the affected area. The purpose of the NDE inspection is to determine if any detrimental damage (i.e. wall thinning, cracks, ovality, buckling) exists. The NDE methods typically used include visual, caliper, ultrasonic, magnetic particle, radiography, and dye penetrant as appropriate. The data are analyzed to assure the pipeline is structurally sound and fit-for-service. If the pipeline is not structurally sound, an engineering design package is prepared to initiate, complete and document the work action. Management of Change and other procedures are applied as required.

### **Section G.2.3 2003 Summary**

In summary, structural related problems are addressed through two processes, first, is a Walking Speed Survey, which inspects piping on a 5-year cycle. Second, are the reported observations of Field and Security personnel of structural anomalies.

In December 2003 there was one structural related pipeline failure (10" W/Z 804) as a result wind induced vibration, or cyclic fatigue. The failure occurred at a mid-span girth weld and the pipeline was shut-in for the remainder of 2003.





## **Section H**

### **2003 Corrosion Monitoring and Inspection Goals**





## Section H Corrosion Monitoring and Inspection Goals

### Section H.1 2003 Corrosion and Inspection Goals Reviewed

Overall, through 2003, the corrosion inspection, monitoring and mitigation programs were expected to be substantially unchanged from 2002. In particular, the corrosion control target of less than 2 mpy remained in place with the inspection and monitoring activity levels to again be substantially as 2002.

#### Section H.1.1 Corrosion Monitoring

The weight loss coupon program frequency was expected to remain unchanged in 2003 compared to the prior year 2002 and is summarized in GPB Table H.1.

<b>Service</b>	<b>Flow Lines (months)</b>	<b>Well Lines (months)</b>
3-phase production	3	4
Produced water	6	8
Seawater	3	3
Processed Oil	3	N/A

**GPB Table H.1 Coupon Pull Frequency**

As a consequence, the activity level from the weight loss coupon program was anticipated to be similar in 2003 to that seen in 2002 and indeed this was the case. There were some changes in 2003 in the number of coupons reported compared to prior years. This is as a result of the following factors:

- Continued efforts to clean historical data records
- Addition of water injection coupons from the facilities to the reported data set
- The removal and addition of equipment associated with abandonment and installation of satellite production equipment.
- The historical data was update to reflect the current equipment inventory

The ER probe program for 2003 was planned to be substantially the same as 2002 with probes being located on the 3-phase production lines. The 2003 result was largely as anticipated with the exception that the level of reliability of the ER probes systems was improved to more consistently deliver data throughout the year.

### **Section H.1.2 Inspection Programs**

The fundamental elements (CRM, ERM, FIP, CIP and CUI) form the foundation for the inspection program. There were no major changes for this program anticipated in 2003 with an overall combined internal and external activity level of 60,000 items.

There were 3 smart pig runs forecast for 2003 and these were completed as planned.

Corrosion under insulation or external corrosion inspection activity was substantially increased in 2002. This increased level of activity was expected again in 2003 with the approximately 35,000 planned items completed as expected.

2003 also represented the conclusion of a 5-year program of work to baseline all the single-line cased piping segments across GPB. At the start of 2003 this was forecast to be approximately 280 cased piping locations. However, as a result of the Y-36 incident, this program ultimately ended-up being substantially greater than this forecast value. All cased piping segments were visually inspected and more than 450 locations were inspected with 'long-range' inspection.

### **Section H.1.3 Chemical Optimization**

For 2003 there were forecast to be no large-scale changes in the corrosion mitigation program and this proved to be the case. However, developments in the small scale testing of corrosion inhibitors continued throughout the year resulting in a substantial increase in well line test results in 2003 compared to prior years.

### **Section H.1.4 Program Reviews**

A number of reviews were conducted during 2003, including:

- **GPB Partner Reviews** – Regular reviews of the corrosion management program at GPB were conducted with the corrosion and integrity experts from the major GPB partners.
- **DOT IMP Audit** – The procedures for analyzing and assessing ILI data and for assessing fitness-for-service for DOT regulated pipelines were presented to the DOT IMP Audit Team. It should be noted that these procedures are substantially the same as those used for non-common carrier pipelines described in this report.
- **BP Internal Integrity Management Review** – A BPXA internal review team conducted an Integrity Management Audit which included a review of the corrosion and inspection program covered under the Charter Agreement

- **ADEC Review** – ADEC and their third party consultant reviewed and commented on the BPXA Corrosion Monitoring Charter Agreement report and Meet and Confer sessions.

### Section H.1.5 2003 Corrective Actions

This section summarizes the corrective actions taken as a result of corrosion monitoring and inspection results exceeding the specified targets. These targets are detailed in Section B.

GPB Table H.2 notes the corrective mitigation actions taken as a result of ER probe readings exceeding target.

Equipment ID	No. of Action	Cause	Action
01D	5	Increased Corrosivity	Increased CI by 30%
01D & 01C	1	Increased Corrosivity	Increased CI by 5%
03D	3	Increased Corrosivity	Increased CI by 25%
05D	1	Increased Corrosivity	Batch Pad. Increased CI 25 gpt
16D	2	Increased Corrosivity	Increased CI by 10%
17D	1	Increased Corrosivity	Increased CI by 5%
F-49	1	Increased Corrosivity	Increased CI by 5%
U-384	1	Increased Corrosivity	Increased CI by 5%
Y-36	6	Increased Corrosivity	Increased CI by 57%

**GPB Table H.2 Corrective Mitigation Actions from ER Probe Data**

GPB Table H.3 notes the corrective mitigation actions taken as a result of weight loss coupons exceeding target.

Equipment ID	No. of Action	Cause	Action
14D	1	Increased Corrosivity	Increased CI by 10%
Q-01	1	Increased Corrosivity	Increased CI, Dilute Pad
Q-01	1	Line Shut-In	No Action
Q-06	1	Line Shut-In	No Action
13B	1	Increased Corrosivity	10% Pad increase

**GPB Table H.3 Corrective Mitigation Actions from Coupon Data**

GPB Table H.4 notes the corrective mitigation actions taken as a result of inspection information.

<b>Equipment ID</b>	<b>No. of Action</b>	<b>Cause</b>	<b>Action</b>
Y-36	2	Increased Corrosivity	Increased CI by 20%
W-74	1	Increased Corrosivity	Increased CI by 10%
PMTCL	1	Increased Corrosivity	Increased CI by 20%
CL16C/17C	1	Increased Corrosivity	Increased CI by 5%

**GPB Table H.4 Corrective Mitigation Actions from Inspection Data**

## **Section H.2 2004 Corrosion Management Goals**

The 2004 corrosion and inspection goals will be focused on the continued delivery and optimization of the current programs. In general, there are not expected to be any substantial changes in the overall scope and scale of the 2004 effort in comparison to 2003.

### **Section H.2.1 Corrosion Monitoring**

There are no plans to significantly change the corrosion weight loss coupon-monitoring program in 2004. The emphasis in the produced water and 3-phase production system will be on sustaining the current level of performance, and in the seawater system maintaining the progress made in 2003.

### **Section H.2.2 Inspection Programs**

The overall 2004 internal inspection program is planned to be substantially unchanged in 2004 from that implemented in 2003. The expected activity level will again be approximately 60,000 inspections items in total distributed between the field and facilities. Of the overall 60,000 inspection items approximately 45% will be associated with cross country flow line and well lines and hence be reported under the Charter Agreement Work Plan.

The external program increased substantially in 2002 with this program increase continuing into 2003 at approximately 35,000 items per year. The current schedule for 2004 is for this level of external corrosion activity to continue at the 2003 pace at 35,000 inspection items for the full year.

2003 saw the completion of the 5-year base-line inspection on all the cased piping segments. As a result of completing the base-line survey the character of the cased piping inspection work will change in 2004 as the program moves into a phase of monitoring and planned mitigation based on the results of the base-line survey work. The 2004 work scope for cased piping is scheduled to be approximately 100 inspections.

The ILI program is planned to be of a similar scale to 2003 dependant upon tool availability and capability.

### **Section H.2.3 Chemical Optimization**

Corrosion inhibition will continue to be the primary means of internal corrosion control at GPB. The emphasis for 2004, as with 2003, will be on the optimization of treatments to minimize the variability in injection rates between planned and actual dosage.

For 2003 the main corrosion inhibitor in use across GPB was unchanged and the program focused on improving the field-testing protocol and analysis techniques. With the introduction of the improved test procedure it is expected that a number of large-scale field trials will take place in 2004 based on the results of the well line test program. While the outcome of these large scale trials can not be predicted, it is anticipated that as a result of the large scale test work, a more effective corrosion inhibitor could be introduced into the field either late 2004 or early 2005.

The changes in the chemical programs in the SW system have reduced corrosion rates, however, the data set available to date is limited and no long-term trends have been established. It is therefore anticipated that there will still be considerable focus on seawater system corrosion rates for 2004.

### **Section H.2.4 Program Improvements and Modification**

**3 Phase Production System** - The 3-phase flow line production system corrosion control is currently operating at approximately 99% conformant with the corrosion rate target of 2 mpy or less. The goal for 2004 will be to move the current level of corrosion control in the well lines toward these higher levels of performance compared with the current level of 95% less than or equal to the 2 mpy target.

**Produced Water System** - The produced water system shows improved levels of corrosion control and therefore the goal for 2004 will be to maintain this level of control as water rates continue to rise across the field.

**Seawater System** - This system has been the focus of significant effort in recent years due to unacceptably high corrosion rates. A number of significant actions have been taken to address dissolved oxygen levels and microbiological corrosion control. These efforts have resulted in data for 2003 showing a significant improvement in corrosion control performance. As noted, this data are preliminary and limited, and therefore the seawater system will continue to be an area of focus and attention through 2004.

**Cased Piping Inspection** - The cased piping inspection completed the 5-year baseline survey in 2003. The program will therefore be evolving in 2004 from this initial assessment activity into a period of monitoring and planned mitigation.





## **Part 2 – Alaska Consolidated Team Performance Unit**

### **Section B-H**





## Section B Corrosion Monitoring Activities

Alaska Consolidated Team (ACT) Performance Unit presently consists of four producing areas: Endicott, Milne Point Unit (MPU), Northstar and Badami. Northstar was added to ACT as it came on production in the second half of 2001. Production from Badami was shut in and the facility mothballed during 2003.

Each of the producing fields within ACT has its own unique set of circumstances and challenges.

**Milne Point** - Located approximately 25 miles west of Prudhoe Bay, the field began production in 1985. On January 1<sup>st</sup>, 1994, BPXA acquired a majority working interest and assumed operatorship. Since 1994 production and proven reserves have been increased and Milne Point production now averages approximately 50,000 bpd.

**Endicott** - Located north of Prudhoe Bay, Endicott consists of two islands, the main Production Island (MPI), and the satellite-drilling island (SDI) at the end of a causeway. Endicott 3-phase production piping is made largely of duplex stainless steel, which significantly reduces the environmental risks. Endicott production averages approximately 27,000 bpd.

**Badami** - Remotely located east of Prudhoe Bay, Badami had a relatively low production volume due to challenging reservoir conditions. The Badami production facilities, like other recent developments on the North Slope, are constructed using a much smaller surface footprint than GPB and do not have permanent road access, therefore having a much reduced impact on the environment. Production from Badami was shut in during the third quarter of 2003. There are currently no plans to bring Badami production back online in the foreseeable future.

**Northstar** - Located offshore, Northstar is the first offshore oil field in the Beaufort Sea not connected to land by a causeway. As with Badami and other recent developments, Northstar drilling and production operations are built on a smaller footprint than the original North Slope facilities. Northstar produces a light, 42 degrees API gravity, high quality sweet crude, that is transported to shore through a pipeline with a wall thickness that is three times that required for pressure containment. Northstar production currently averages approximately 70,000 bpd.

ACT Table B.1 illustrates, on a relative basis, the unique corrosivity of each producing field within ACT along with the materials of construction and corrosion mitigation. GPB is included in the table for comparative purposes. Listed in the table are, for each field, the typical water cut in percent, average wellhead temperature, and the percent CO<sub>2</sub> in the produced gas.

Field	Prod Fluid Characteristics				Material of Construction <sup>(a)</sup>			
	H <sub>2</sub> O (%)	T (°F)	P <sub>CO<sub>2</sub></sub> (%)	CR <sup>(b)</sup>	Production		Injection	
					WL	FL	WL	FL
GPB	72	150	12	H	CS+CI	CS+CI <sup>(c)</sup>	CS+CI	CS+CI
END	89	150	18	H	DSS	DSS	CS+CI	CS+CI
MPU	49	125	1.5	L/M	CS	CS <sup>(d)</sup>	CS+CI	CS+CI
Northstar	4	160	5	M	CS+CI	N/A	N/A	N/A
Badami	~0	65	~0	L	CS	N/A	N/A	N/A

## Notes

- (a) CS is carbon steel, CI is corrosion inhibitor, DSS is duplex stainless steel  
 (b) Unmitigated relative corrosion rate, H – high, M – medium, and L – low  
 (c) There are a limited number of Duplex Stainless Steel flow lines in GPB  
 (d) Two production flow lines are inhibited at MPU

**ACT Table B.1 Relative Corrosivity of BPXA North Slope Production**

Badami, MPU, and Northstar production fluids have a lower corrosivity compared to GPB. Endicott's production fluid characteristics are more corrosive than GPB and this corrosion risk is mitigated largely through the use of duplex stainless steel (DSS).

ACT Table B.2 shows the ACT fields combined are of a much smaller scale than GPB. For example, neither Northstar nor Badami have any significant non-common carrier cross-country flow lines. Also, it should be noted, that when comparing GPB and ACT facilities, these facilities vary in age from over 26 years for GPB to ~24 months for Northstar.

Metric	ACT	GPB	$\frac{\text{ACT}}{(\text{ACT} + \text{GPB})} \%$
Number of Production Trains	4	21	16%
Number of Prod and Inj Wells	230	1,475	13%
Non-common carrier FL miles	105	1,350	7%
Total Acreage	75,000	203,000	27%

**ACT Table B.2 Illustrative Comparison of Scale Between ACT and GPB****Section B.1 Endicott**

Endicott is a mature waterflood field. The fluid properties (high temperatures, high CO<sub>2</sub> content) indicate the corrosivity of the produced fluids to be high. Due to this high corrosivity, the majority of the oil production system was fabricated from duplex stainless steel, a corrosion resistant alloy and therefore, corrosion is

not a significant concern for this system. In the oil production system, the only carbon steel is the C-Spool, connecting the wellhead to the duplex stainless steel well line. These C-Spools are inspected regularly and replaced when no longer fit-for-service as per the criteria discussed in Section E.3. ACT Table B.3 reflects the historical inspection activity level for Endicott.

Service	Length (Miles)	Int. Insp.			Ext. Insp. <sup>1</sup>		
		2001	2002	2003	2001	2002	2003
Oil x-country lines	3.5	4 (in vault)	4 (in vault)	14 (4 in vault)	4 (in vault)	4 (in vault)	4 (in vault)
Oil - Well Pads	2.5	1,134	1,327	1,531	-	-	-
Water x-country lines	3.5	104	104	229	4 (in vault)	4 (in vault)	4 (in vault)
Water - Well Pads	1.7	194	200	224	2 (in vault)	9 (in vault)	5
Gas x-country (GLT/MI)	7	4 (in vault)	15	45	4 (in vault)	4 (in vault)	774
Gas - Well Pads	1.2	40	26	29	2 (in vault)	9 (in Vault)	69
Fuel Line - Gasoline	N/A	-	5 foot excavation	-	-	5 foot excavation	-
Fuel line - diesel	N/A	-	5 foot excavation	-	-	5 foot excavation	-
<b>Totals</b>		<b>1,480</b>	<b>1,686</b>	<b>2,072</b>	<b>16</b>	<b>40</b>	<b>856</b>

<sup>1</sup> The external corrosion program concentrated significantly on the Oil Sales line in 2002

**ACT Table B.3 Endicott Summary of Lines and NDE Inspections**

The primary corrosion concerns are in the water injection system, mainly the Inter-Island Water Line (IIWL) carrying injection water to the satellite drilling island (SDI) from the main production island (MPI). Corrosion control of the water injection system relies on corrosion inhibition of the injection water, supplemented by a biocide and maintenance pigging program. The effectiveness of corrosion control on the IIWL is monitored by ultrasonic inspection at 25 locations.

## Section B.2 Milne Point

The primary corrosion concerns are in the water injection system and external corrosion of buried piping. Corrosion inhibition, supplemented by a biocide and maintenance pigging program began in mid-2000 in the water injection system. As a result, corrosion rates, as exhibited by weight loss coupons, have dropped significantly over the past three years.

Although the low temperatures and low CO<sub>2</sub> content of the production fluids result in lower corrosivity for MPU, solids contribute to the corrosion mechanism of the production system. Corrosion inhibition of the K-pad production flow line was initiated in 2001 and the F-L-C Pads flow line in 2003. Additionally, corrosion inhibition of the newly developed S-Pad began late 2002.

ACT Table B.4 reflects the historical inspection activity for MPU from 2001-2003.

Service	Length (Miles)	Int. Insp.			Ext. Insp.		
		2001	2002	2003	2001	2002 <sup>2</sup>	2003
Oil x-country lines	24	73	80	465	225	-	964
Oil – Well Pads	N/A <sup>1</sup>	363	754	2,754	265	47	N/A <sup>3</sup>
Water x-country	15	29	35	185	138	-	97
Water – Well Pads	N/A <sup>1</sup>	90	449	635	142	23	N/A <sup>3</sup>
Gas x-country	14	31	-	20	715	-	522
Gas – Well Pads	N/A <sup>1</sup>	43	283	99	92	-	N/A <sup>3</sup>
Water/Alternating Gas Well Pads	N/A <sup>1</sup>	-	-	230	-	-	-
<b>Totals</b>		<b>629</b>	<b>1,601</b>	<b>4,388</b>	<b>1,577</b>	<b>70</b>	<b>1,583</b>

<sup>1</sup> Totals not available

<sup>2</sup> The external corrosion program concentrated significantly on the Oil Sales line and outside facility piping in 2002.

<sup>3</sup> Included with internal numbers as part of the excavations.

**ACT Table B.4 MPU Summary of Lines and NDE Inspections 2003**

## Section B.3 Northstar

Northstar began production in November 2001. Production fluid corrosivity is low to moderate, but will tend to increase over time with the injection of GPB gas into the reservoir. ACT Table B.5 summarizes the inspection program for Northstar from 2001- 2003. Data are limited as the production facility is relatively new.

Service	Length (feet)	Int. Insp.			Ext. Insp.		
		2001	2002	2003	2001	2002	2003
Oil Pipe rack	1,200	-	-	-	-	-	-
Oil – Well Pad	280	12	106	114	-	-	-
Water Pipe rack <sup>1</sup>	2,400	-	-	-	-	-	-
Water – Well Pad <sup>1</sup>	70	-	17	25	-	-	-
Gas Pipe rack	600	-	-	-	-	-	-
Gas – Well Pad	140	4	26	65	-	-	-
Totals		16	149	204	-	-	-

<sup>1</sup> Disposal system; Northstar does not have an active water injection system.

**ACT Table B.5 Northstar Summary of Lines and NDE Inspections 2003**

## Section B.4 Badami

Low productivity necessitated the shut-in of the Badami Field in the third quarter of 2003. Shut-in consisted of de-inventory and mothball of major equipment. Prior to shut-in, Badami's production fluids were considered a low risk from a corrosivity standpoint, as there is little water production and low CO<sub>2</sub> content. ACT Table B.6 summarizes the inspection program for Badami.

Service	Length (Feet)	Int. Insp.	Ext. Insp.
Oil –Well Pad	840 WL, 320 HDR	21	-
Gas	240 WL, 320 HDR	5	-
Disposal Well	400	3	-

Note: Badami does not have an active water injection system.

**ACT Table B.6 Badami Summary of Lines and NDE Inspections 2003**

## Section B.5 Overall Inspection Activity Level

ACT Table B.7 summarizes the overall inspection activity since 2000. As can be seen, the overall activity level has remained approximately constant at ~3,400 items per year through 2002. However, a significant increase in inspections occurred in 2003. This is the result of additional external inspections performed at Endicott and the additional internal inspection at Endicott and MPU.

Part 2 – Alaska Consolidated Team Performance Unit

	<b>Surface</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>
Endicott	Int	1,346	1,480	1,686	2,072
	Ext	16	16	40	856
	<b>Total</b>	<b>1,362</b>	<b>1,496</b>	<b>1,726</b>	<b>2,928</b>
Milne Point	Int	1,419	629	1,601	4,388
	Ext	378	1,577	70	1,583
	<b>Total</b>	<b>1,797</b>	<b>2,206</b>	<b>1,671</b>	<b>5,971</b>
Northstar	Int	-	16	149	204
	Ext	-	-	-	-
	<b>Total</b>	<b>-</b>	<b>16</b>	<b>149</b>	<b>204</b>
Badami	Int	27	-	5	29
	Ext	-	-	-	-
	<b>Total</b>	<b>27</b>	<b>-</b>	<b>5</b>	<b>29</b>
<b>Grand Total</b>		<b>3,186</b>	<b>3,718</b>	<b>3,551</b>	<b>9,132</b>

**ACT Table B.7 Overall Inspection Activity Summary 2000 – 2003**



## Section C Weight Loss Coupons

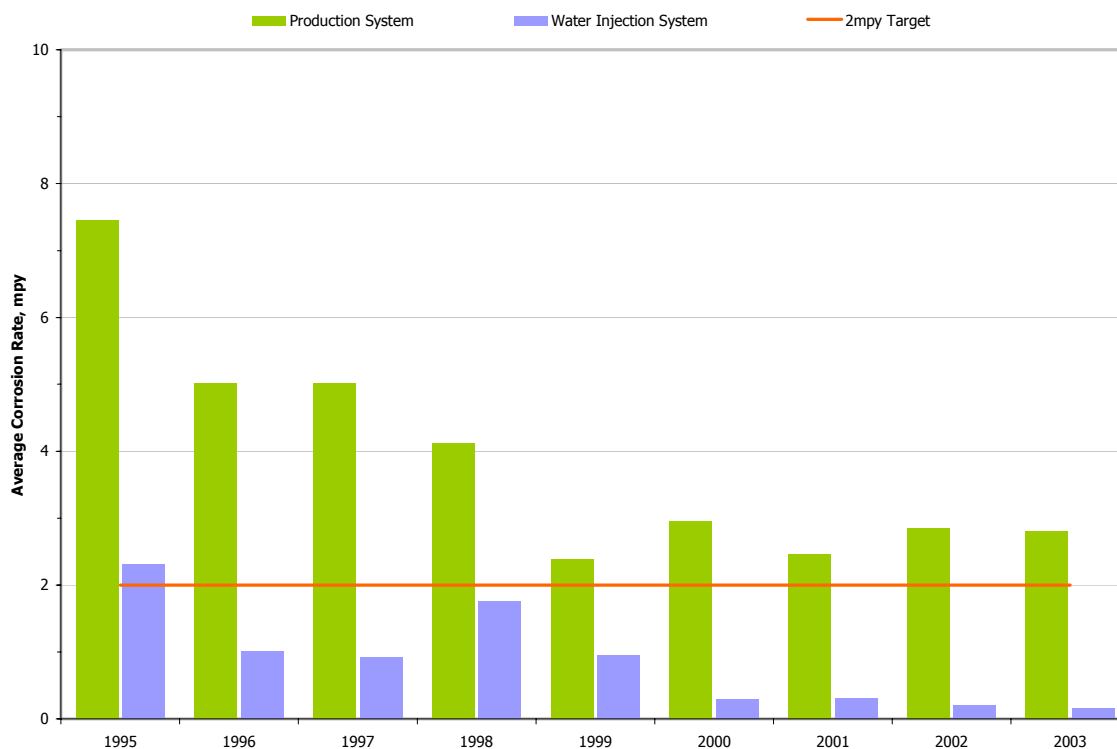
### Section C.1 Endicott

ACT Table C.1 summarizes the corrosion monitoring performance for 2003 and historical data are shown in ACT Figure C.1.

The corrosion trend for the production system has remained above 2 mpy; however as noted previously, the major portion of the system is fabricated from DSS and the data are used primarily for monitoring produced fluid corrosivity and erosion tendency. The lower, relatively constant corrosion rates in the water injection system reflect the effectiveness of the corrosion mitigation program. No WLC corrosion rates above 2 mpy were experienced at Endicott in the water injection lines in 2003.

System	Access Fittings	WLC <2 mpy
Water Injection - Pads	15	100%
Water Injection – x-country	1	100%
Oil Production – Pads	76	70%

**ACT Table C.1 Endicott Corrosion Coupon Monitoring 2003**



**ACT Figure C.1 Corrosion coupon data from Endicott 1995-2003**

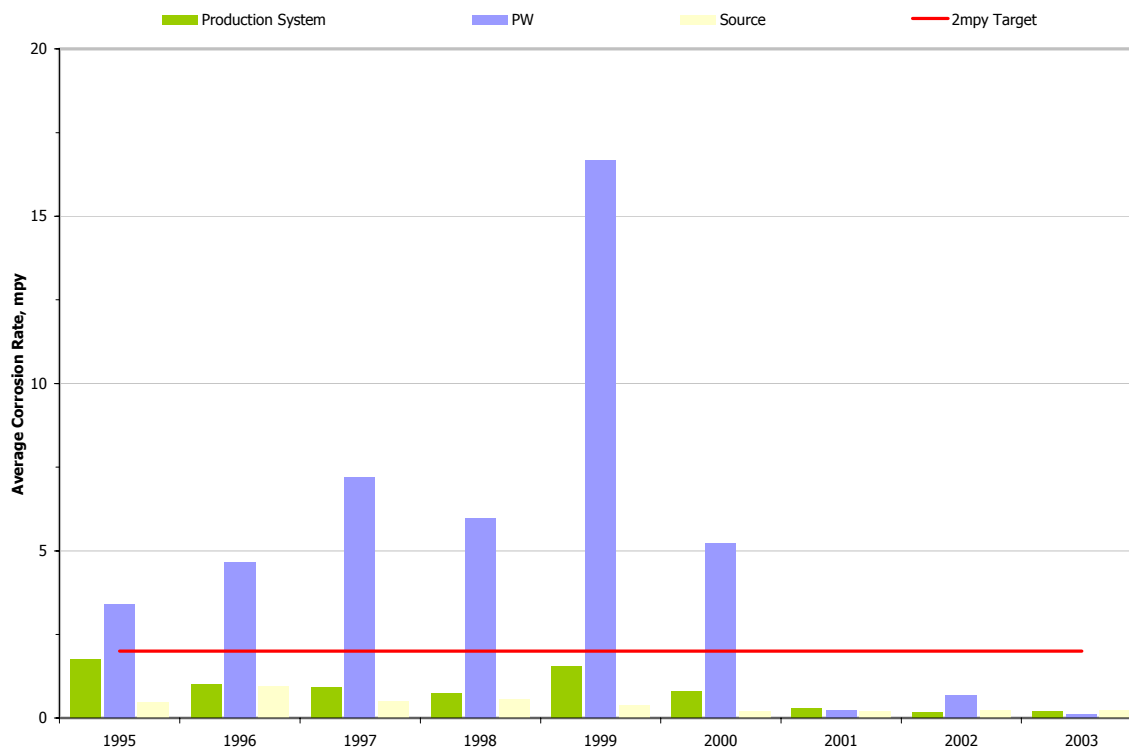
## Section C.2 Milne Point

ACT Table C.2 summarizes the corrosion monitoring performance for 2003 and historical data are shown in ACT Figure C.2.

ACT Figure C.2 illustrates the low corrosion rates for the MPU production and source water systems. Of concern historically were the relatively higher corrosion rates in the water injection system. These higher corrosion rates led to the initiation of corrosion inhibition in the water injection system in mid-2000. The monitoring results indicate the inhibition is having a positive effect on the corrosion rate as the WLC corrosion rates have consistently averaged less than 2 mpy.

System	Access Fittings	WLC <2 mpy
Production System	27	100%
Water Injection System	8	100%
Source Water Coupons	6	100%

**ACT Table C.2 MPU Corrosion Coupon Monitoring 2003**



**ACT Figure C.2 Corrosion coupon data from MPU 1995-2003**

The historical WLC corrosion rate for the produced water system is greater than shown in previous reports. This is due to a reclassification of service correcting several coupons previously identified as being in produced water service to source water service.

### Section C.3 Northstar

ACT Table C.3 shows the results of the corrosion monitoring program at Northstar for 2003. There are no historical data prior to 2003.

System	Location	Access Fittings (Pad)	No. WLC >2 mpy	% WLC <2 mpy
Oil Production				
	Upstream of CI Injection	8	7	13%
	Downstream of CI Injection	4	-	100%
Water Disposal				
	Upstream of Mud Addition	6	-	100%
	Downstream of Mud Addition	1	1	0%

**ACT Table C.3 Northstar Corrosion Coupon Monitoring 2003**

The 3-phase production is currently inhibited; however monitoring data indicate the corrosion rates are above the 2 mpy target. The reason is the corrosion monitoring locations are upstream of the corrosion inhibitor injection location. The table shows the inhibition program is effective in reducing corrosion rates to acceptable levels, as indicated by the monitoring locations downstream of the injection point in the facility. The coupons from the upstream location indicate the need for inhibition of the upstream section. Recommendations have been made to move the corrosion inhibitor injection further upstream to the wellhead.

The high corrosion rates in the water disposal well have been caused by highly oxygenated mud from the drilling project grind-and-inject plant. Although an oxygen scavenger has been tested in the grind-and-inject fluids, it has shown to be ineffective due to the low fluid temperatures. The drilling rig and the grind-and-inject plant are scheduled to shut down in the first quarter of 2004 and it is anticipated the corrosion rate will be reduced to the acceptable levels as seen in upstream portions of the water disposal system.

### Section C.4 Badami

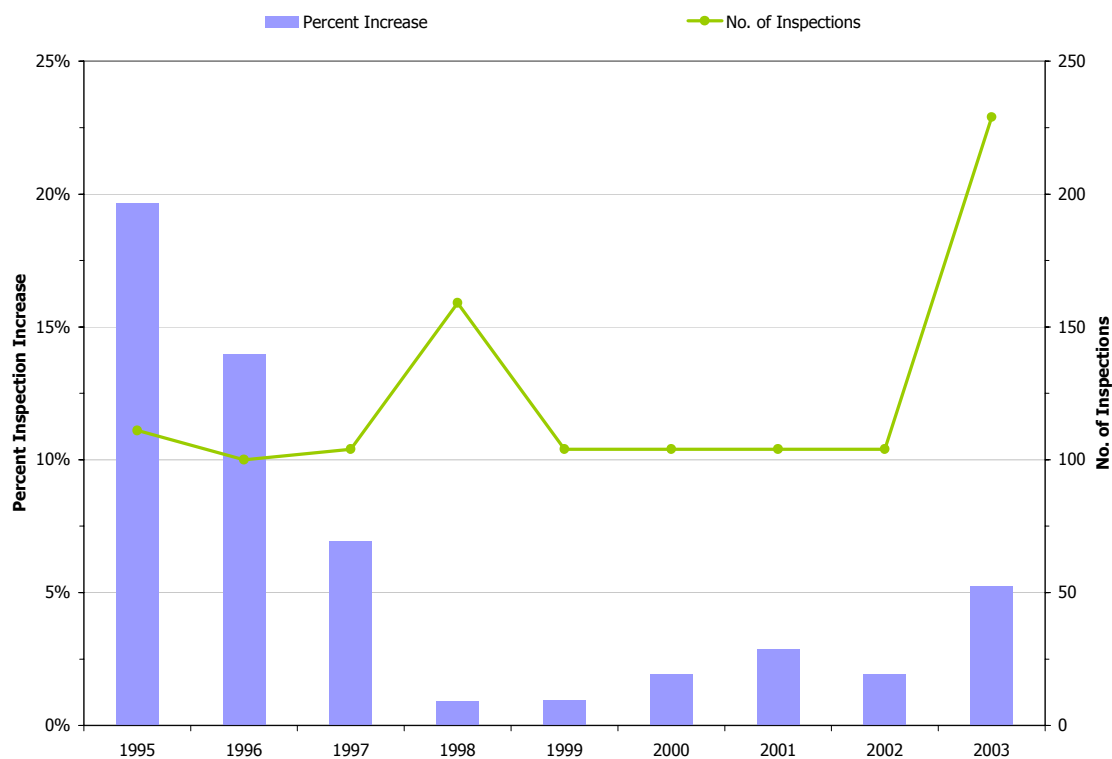
Badami currently has no WLC-monitoring program, but relies on an inspection program presented in Section E.

## Section D Corrosion Mitigation Activities

### Section D.1 Endicott

Corrosion mitigation for the IIWL relies on maintenance pigging for line cleanliness, biociding to control bacterial activity and continuous injection of a corrosion inhibitor for corrosion control. The primary monitoring tool for effectiveness of these programs is UT inspection.

ACT Figure D.1 shows there is an increase in corrosion activity in the IIWL in 2003 compared with 1998 to 2002. While the 2003 results are cause for concern, the results are still below the levels seen prior to 1997. The number of locations showing corrosion increases has been fairly constant over the previous three years, indicating slight corrosion activity. Unfortunately the maintenance pigging program was suspended for approximately 12 weeks in 2003 for repairs to the launcher. As a result of the pigging suspension, the IIWL experienced an increase in corrosion activity. To monitor the corrosion activity, the inspection frequency was changed from quarterly to monthly until control is once again assured. Pigging was resumed in late 2003 and current inspection data indicate corrosion is under control.



**ACT Figure D.1 Endicott IIWL UT Readings Through 2003**

As well as maintenance pigging, corrosion control of the IIWL relies on corrosion inhibition and biocide. Treatment volumes vary dependant upon operational

swings in injection rates and reservoir optimization efforts. However, as an additional preventative measure the continuous corrosion inhibitor concentration was increased by 17½% to 20 ppm.

In the production system, the primary damage mechanism is erosion. The erosion rate is monitored through inspection and mitigated through velocity management. Wells are risk ranked by mixture velocity once per month and the information is used to adjust the inspection frequency and fluid velocity. ACT Table D.1 is an overview of the velocity data for 2001 to 2003. Shown are the number of wells within L/R ratio ranges, where L is the mixture velocity and R is the allowable erosion velocity as defined by API RP 14E<sup>9</sup>.

L/R Range	2001		2002		2003	
	No. Wells	Percent	No. Wells	Percent	No. Wells	Percent
L/R<1	23	38%	12	21%	19	31%
1<L/R<2	25	42%	31	54%	29	47%
2<L/R<3	11	18%	12	21%	13	21%
L/R>3	1	2%	2	4%	1	2%
Total	60	100%	57	100%	62	100%

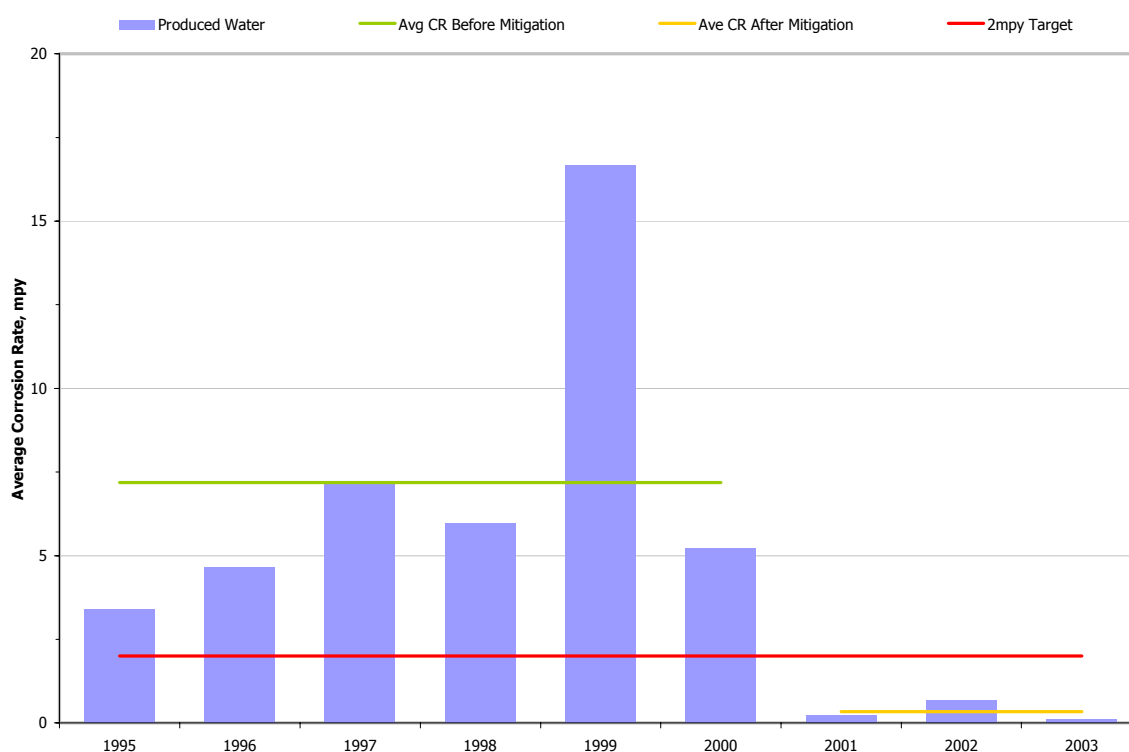
**ACT Table D.1 Endicott Velocity Monitoring 2001-2003**

API RP 14E defines an allowable velocity for the avoidance of erosion, based on the fluid properties (namely density) and material of construction. API RP 14E is based on experience with steam service and is known to be conservative when applied to oil production systems, particularly where corrosion and erosion resistant materials are used. Actual velocities are expressed as a ratio of the allowable velocity as defined by API RP 14E, with the aim being to limit velocities to less than 3 times the allowable velocity. This factor of 3 reflects BPXA's experience that production fluids with minimal amounts of entrained solids may exceed the API RP 14E erosion velocity through stainless steel pipelines by this amount with minimal risk of erosion. Equipment exhibiting high velocities is inspected at intervals ranging from weekly to bi-annually dependant upon the L/R Ratio, input from Well Operations, and inspection results. The inspection frequency for the well showing an L/R Ratio greater than 3 has been increased from quarterly to monthly.

<sup>9</sup> API-14E - Recommended Practice for Design and Installation of Offshore Production Platform Piping System 5<sup>th</sup> Edition.

## Section D.2 Milne Point

Corrosion inhibition of the water injection system began in mid-2000, in addition to a more frequent maintenance pigging program. Corrosion inhibitor concentration is at 40 ppm. Weight loss coupon data indicate the system is coming under control as the WLC corrosion rates have averaged less than 2 mpy since mid-2000. This represents a significant reduction from previous years as can be seen in ACT Figure D.2. For the period 1996-2000, the average corrosion rate was ~7 mpy. Since the enhancement of the corrosion management program in 2000, the average WLC corrosion rate for the PW system has been reduced to less than 1 mpy.



**ACT Figure D.2 Milne Point Produced Water Corrosion Rate Trend**

Corrosion inhibition on the K-Pad 3-phase production flow line was initiated in 2001 after inspections indicated significant under-deposit corrosion damage. The damage was associated with low fluid velocities, allowing solids to accumulate in the line. In conjunction with the inhibition program, the K-Pad flow line is cleaned with a maintenance pig on approximately a monthly basis. Inhibition levels were increased in October 2003 when additional increasing damage was

noted in the line. The current inhibition level based on water production is 80 ppm versus 56<sup>10</sup> ppm, originally.

The K-pad 3-phase flow line will be a focus of activity during 2004 to assure the corrective action identified above result in a decrease in the corrosion activity.

The development at S-Pad was designed for continuous inhibition injection into the power fluid supply for the downhole hydraulic pumps. Since this water is separated and re-circulated as power fluid at the pad, approximately ten percent of the produced water is sent through the cross-country flow line to the separation facility. Additional makeup water for use in the power fluid system is treated at a rate of 20-ppm corrosion inhibitor. This program will be optimized based on the results from the inspection and corrosion monitoring programs.

Continuous inhibition was initiated in flow line carrying production from F, L, and C Pads in 2003 due to corrosion damage detected with the 2002 ILI. The initial injection rate was set at 56 ppm. Adjustments to the corrosion inhibitor concentration will be dependent on results of corrosion monitoring program.

The remaining uninhibited production flow lines are under review for corrosion inhibition. Inspection increases in these production well lines indicates there is slight corrosion activity occurring over the long term. This evaluation is expected to be completed and recommendations made in 2004.

As production rates are typically low for the pipeline capacity, the fluid velocities are low and erosion is not a significant concern, therefore there is no formal velocity management program.

### **Section D.3 Northstar**

Northstar is inhibited with continuous injection of corrosion inhibitor into the well production lines. Inhibitor concentration is set at 100 ppm based on water rates, with a minimum of 2 gallons/day regardless of the production characteristics.

As noted in Section C.3, a recommendation has been made to relocate the chemical injection upstream to the wellhead.

### **Section D.4 Badami**

Corrosion inhibition was not required at the Badami field based on modeling of the corrosivity of the fluids, the low water-cut, and the results from the facility and pipeline inspection program.

---

<sup>10</sup>The treatment rate reported in the 2002 Annual Report was incorrectly stated at 100 ppm.

## Section E External/Internal Inspection

### Section E.1 External Inspection

#### Section E.1.1 Endicott

Cased flow lines at Endicott are inspected by electromagnetic pulse test (E-Pulse) per the frequency listed in ACT Table E.1. During the most recent inspection, no significant anomalies were noted.

Line	Crossings	Year Surveyed	Method	Max Inspection Interval
Water - Inter-Island	1	2001	E-Pulse	10 Years
Gas Lift - Inter-Island	1	2001	E-Pulse	10 Years
Oil	1	N/A		N/A Duplex Stainless Steel
MI Line	1 <sup>1</sup>	N/A		
Water – WL	2	1 line in 2000	E-Pulse	10 Years for Carbon Steel Other line is Duplex Stainless Steel
Gas - WL	1	2000	E-Pulse	10 Years

<sup>1</sup> New in 1998, inspection ports for sniffing, permanently sealed, can be inspected by excavation only

**ACT Table E.1 Cased Piping Inspections**

In addition, the vaults where the production, IIWL, and gas-lift pipelines pass are visually inspected annually. Minor external corrosion has occurred, but no increased activity was observed in 2003.

In 2003, the MI and gas-lift pipeline were inspected with tangential radiography and no increase in corrosion damage was found. Producing well 5-01 was inspected and found to have external corrosion; the damaged section was replaced.

#### Section E.1.2 Milne Point

ACT Table E.2 summarizes the external inspection program at MPU since 1997. Sixty-six (66) small-scale excavations were completed throughout the MPU field in 2003. The locations were focused on piping along the roadways for Tract 14 and L-Pad.



<b>Year</b>	<b>Total Insp</b>	<b>Repeat Insp</b>	<b>Increases</b>	<b>% I's</b>
1997	26	0	0	n/a
1998	441	10	0	0.0
1999	101	65	0	0.0
2000	205	104	28	26.9
2001	179	20	5	25
2002	70	5	1	20
2003	1583	55	1	1.8

**ACT Table E.2 MPU Inspection Summary - External**

Tract 14 excavations included the production header; test header and water injection header weld packs. Of the locations selected, 36 were previously un-inspected and 13 were repeat locations. All three headers were found to be free of external corrosion.

The L-Pad roadway piping inspection included 12 weld packs along the previously abandoned oil piping and in-service water injection piping. No external corrosion was noted for either pipeline. The water injector was found to have internal corrosion at all locations, however no repairs were required.

L-Pad headers were excavated at five locations and found to have external corrosion on both the production and test headers, which required one well line repair. As a result, an above ground header has replaced the buried production header. The buried header has been drained of fluids, blinded and inerted with nitrogen.

### **Section E.1.3 Badami**

External inspections that have been done to date at Badami are associated with the internal inspection program where insulation was removed for ultrasonic inspection of well line elbows. No evidence of corrosion was noted.

### **Section E.1.4 Northstar**

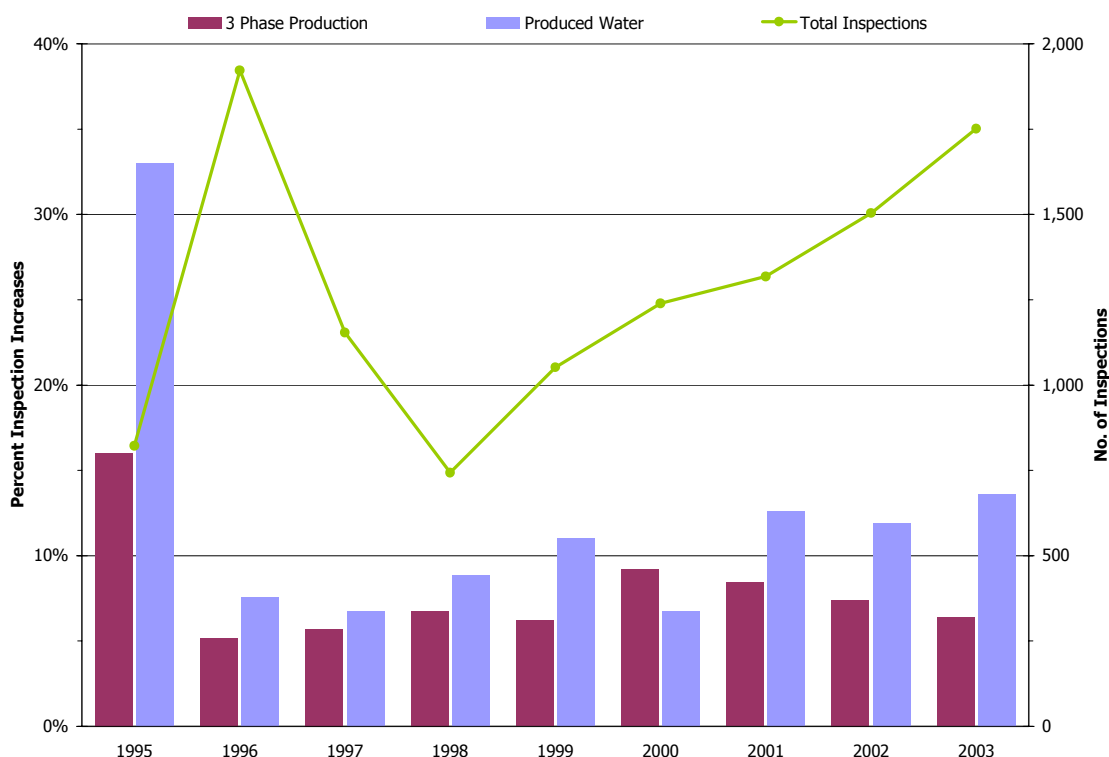
Since the facility is less than 3-years old, an external inspection program has not yet been established. Based on GPB experience, CUI typically takes several years to initiate. A program will be implemented within 5-years from startup (2006).

## Section E.2 Internal Corrosion Inspection

### Section E.2.1 Endicott

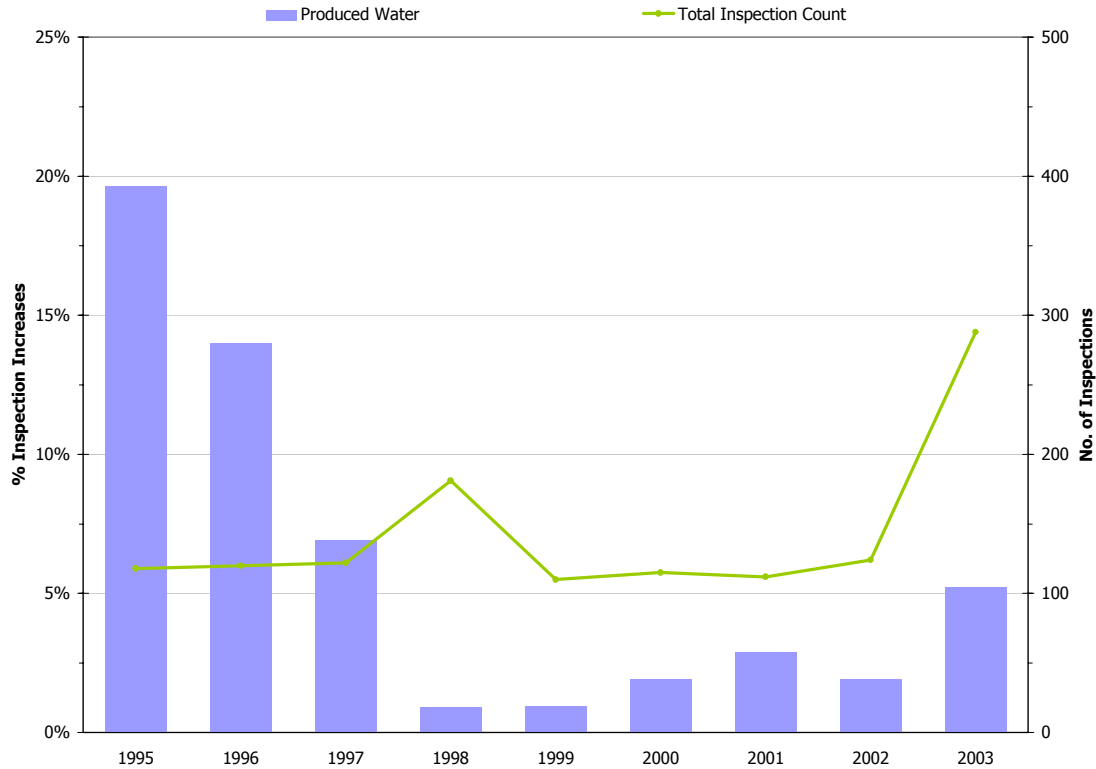
ACT Figure E.1 and ACT Figure E.2 indicate the percentage of inspection increases since 1995 for the well lines and flow lines at Endicott. There were no increases in the 3-phase, DSS production cross-country line. The production system inspection data are used to alert Operations of potential replacements of the carbon steel C-Spools at the wellheads.

Corrosion activity in the water injection well lines has risen since 1998 and has been addressed by increasing the corrosion inhibition concentration by 17½% as previously noted.



**ACT Figure E.1 Detection of internal corrosion of well lines by inspection at Endicott 2003**

ACT Figure E.2 shows a significant decline of inspection increases from 1995 through 1998 for the IIWL at Endicott. There has been a gradual increase in inspection increases since 1998. As discussed in Section D.1, the increase in corrosion activity in the IIWL was exacerbated by the temporary suspension in the pigging program and addressed by an increase in corrosion inhibition in 2003.

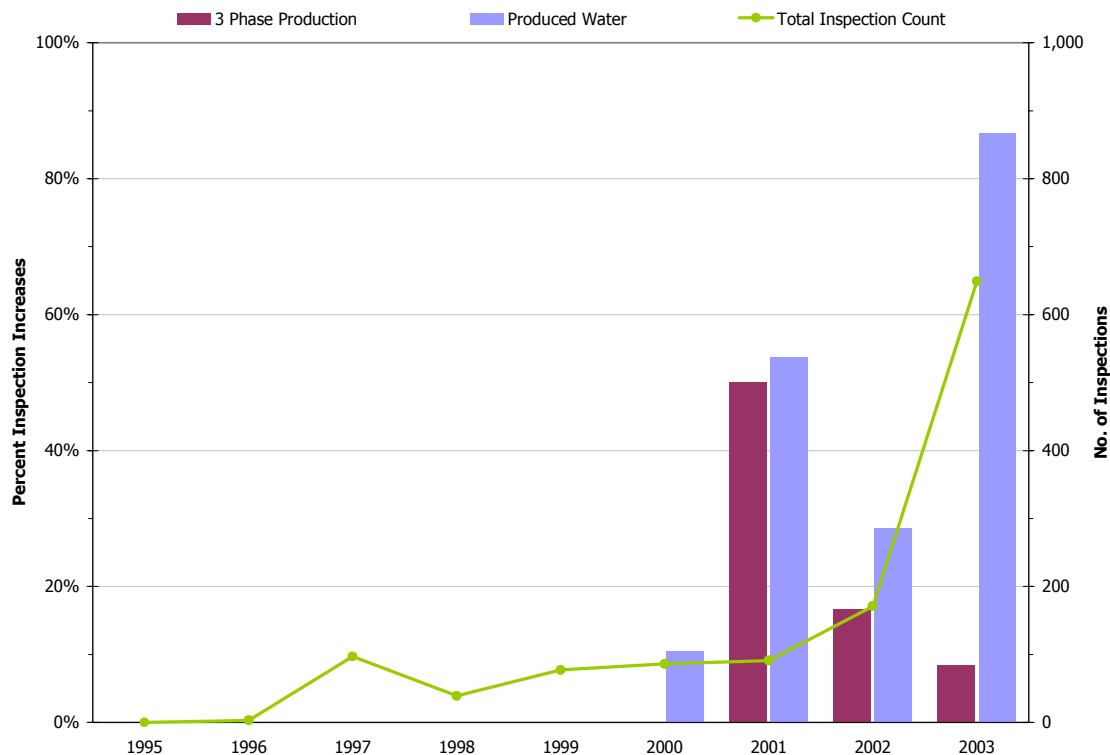


**ACT Figure E.2 Detection of internal corrosion of flow line by inspection at Endicott 2003**

It should be noted that the corrosion increases in the 3-phase production are in carbon steel C-Spools that are managed through planned replacement at the FFS criteria discussed in Section E.3.

### Section E.2.2 Milne Point

During the period of 1994-2000, the inspection program established a baseline condition of the production facilities and pipelines. Since 2000, trending of inspection increases has been made possible with repeat inspections. The results of this comparative data can be seen in ACT Figure E.3. The figure shows that the total number of inspection items has consistently increased since 1998.



**ACT Figure E.3 Detection of internal corrosion of flow lines by inspection at MPU 2003**

The percentage of repeat locations in produced water flow lines shows a significant increase in 2003, up to 87% from 29% in 2002. The increases are believed to be the result of inspections which cover the period before and after the establishment of corrosion control as shown in ACT Figure D.2. These lines were put on corrosion inhibition in the latter half of 2000. The average time between inspections is on the order of 4-5 years, indicating much of the corrosion noted may have occurred prior to the establishment of corrosion inhibition.

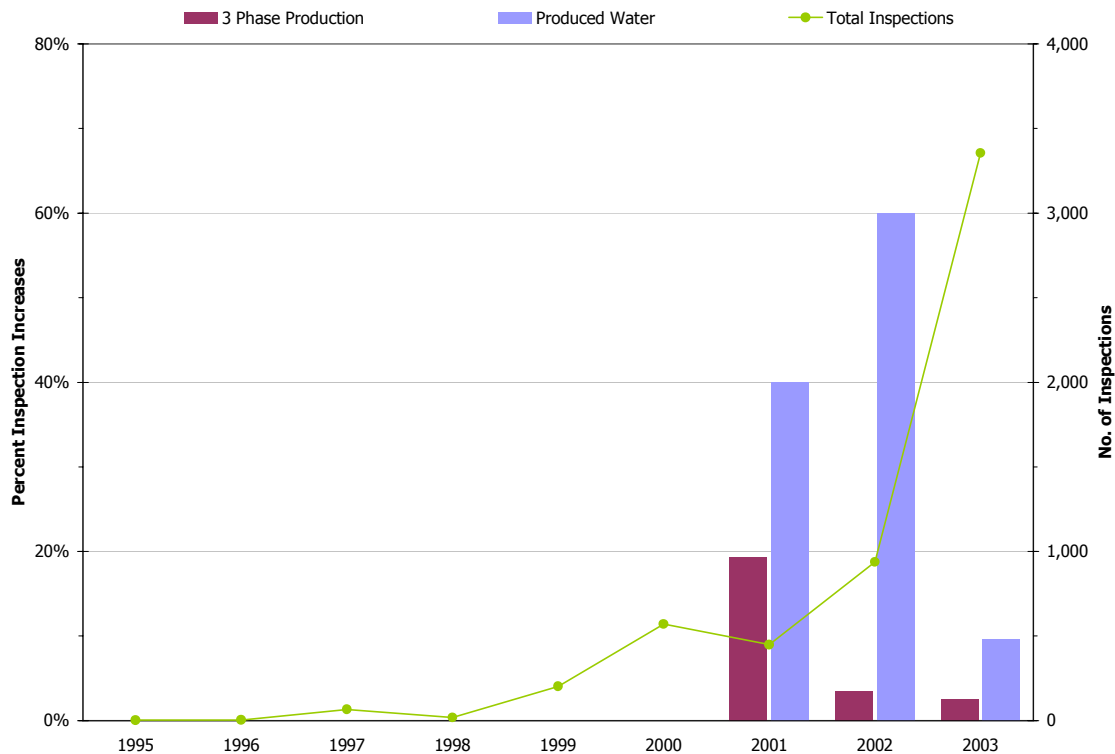
The effectiveness of the corrective actions is demonstrated by low WLC corrosion rates since corrosion inhibition was established. The well line repeat inspections are much closer to a year apart on average for 2003 as compared to 2002. As a result, the well line repeat inspections showing active corrosion have dropped significantly.

The produced water system will be monitored carefully to assure that the above analysis is correct and that corrosion control has been established.

Overall the 3-phase flow lines continue to show a decreasing trend of locations with corrosion activity. This is a direct result of increased inhibition of 3-phase flow lines at MPU. However, an expanded inspection program on the K-Pad flow line has identified six locations requiring sleeve repair in 2003. Inhibition levels were increased in the third quarter of 2003 as a result of this additional damage.

Further verification of 2001 ILI data has confirmed the upstream section of the F-Pad flow line has internal corrosion damage. As a result, corrosion inhibition program was established in 2003, subsequent inspection of these areas in late 2003 reveals no increased corrosion damage.

ACT Figure E.4 shows the historical detection of internal corrosion of well lines by inspection and the progress made in expanding the inspection program. There has been a significant decrease in the number of repeat locations showing active corrosion from 2002 to 2003. As noted in the discussion above, this represents a more consistent repeat inspection basis from prior years, as the majority of repeat locations were at approximately a year apart, whereas in previous years the time difference between repeat inspections was several years.



**ACT Figure E.4 Detection of internal corrosion of well lines by inspection**

ACT Table E.3 shows the results from the inspection program for the recent S-Pad development. A total of 1,500 3-phase and 179 produced water locations were inspected in 2003 on 34 wells. Of the 1,679 total inspections performed, 1,477 were repeat locations. The inspection results indicate corrosion activity is relatively minor with only 16 locations showing an increase. All locations showing corrosion activity are re-inspected on a monthly basis.

	<b>3-Phase</b>	<b>PW</b>	<b>Total</b>
Number of Inspections	1,500	179	1,679
Number of Repeat Insp	1,305	172	1,477
Number of Insp with Damage	16	0	16

Notes: Data represents inspections from 34 wells  
All damage locations being evaluated on a monthly basis

**ACT Table E.3 Inspection Summary of MPU S-Pad**

### **Section E.2.3 Badami**

The Badami Field was shut in August of 2003 due to declining productivity. There are currently no plans to produce the field. A post shutdown inspection was performed to serve as a baseline for a follow-up inspection in the third quarter of 2004 as a check to assure equipment was properly laid up.

Although the data set is limited, inspections support the overall assertion that Badami fluids have low corrosivity. ACT Table E.4 is a summary of well line inspections for Badami. Only one location has shown an increase in inspection damage. The interval between inspections suggests the increased damage was associated during shutdown work.

<b>Year</b>	<b>Oil</b>	<b>Gas</b>	<b>Disposal</b>	<b>Total</b>	<b>Repeat Insp</b>	<b>Locations with Increasing Damage</b>
1998	28	3	-	31	0	-
1999	-	-	-	-	-	-
2000	15	6	6	27	18	0
2001	-	-	-	-	-	-
2002	5	-	-	5	4	0
2003	21	5	3	29	19	1

Note: Increasing damage location associated with shutdown operation

**ACT Table E.4 Inspection Summary of Badami well Lines**

### **Section E.2.4 Northstar**

During 2003, a total of 204 well line inspections were completed, up from 146 the previous year. Four locations in the 3-phase system and two locations in the water disposal system had an inspection increase. No increases were experienced in the gas system. The four 3-phase locations showing corrosion are all in heavy wall target tees and are currently monitored on a quarterly basis.

The water disposal well problems are associated with the mud plant operation have been discussed previously. It is anticipated that when the mud plant shuts down operation, the corrosion rates will be lower as seen in locations further upstream of the system. This data are summarized in ACT Table E.5.

	<b>3-Phase</b>	<b>Disposal</b>	<b>Gas</b>	<b>Total</b>
Number of. Inspections	114	25	65	204
Number of Repeat Inspections	94	25	60	179
Locations with Increasing Damage	4	2	0	6

**ACT Table E.5 Inspection Summary of Northstar**

## Section F Repair Activities

ACT Table F.1 summarizes the repair activity for ACT. There were 14 repairs identified for ACT of which 7 were at Endicott and 7 at Milne Point.

<b>Service</b>	<b>Type</b>	<b>Int</b>	<b>Ext</b>	<b>Mechanical</b>
Oil	FL	5	1	0
	WL	6	0	0
Gas	FL	0	0	0
	WL	0	1	0
PW	FL	0	0	0
	WL	1	0	0
<b>Total</b>		<b>12</b>	<b>2</b>	<b>0</b>

**ACT Table F.1 ACT Repair Activity**

Four of the Endicott repairs were production well lines; three C-spool replacements due to internal corrosion and one pipe spool replacement due to erosion. One spool replacement was in a water injection well line due to internal corrosion. One spool replacement was in gas injection well line due to external corrosion. One sleeve was installed on a duplex stainless steel well line due to erosion.

Six of the Milne Point repairs were all on the K-pad production flow line of which one was due to external corrosion. Additional areas have been identified for sleeve repair.

The Milne Point L-Pad well line and production headers were found to have external corrosion upon excavation. The entire header was redirected above ground and the existing header was drained and abandoned in place.



## Section G Corrosion and Structural Related Spills and Incidents

There was no corrosion or structural related spills in ACT in 2003. ACT Table G.1, ACT Table G.2, ACT Table G.3, and ACT Table G.4 summarize leak/save and mechanical repair data for Endicott, MPU, Northstar and Badami, respectively.

Service	Leaks	Saves	Sleeves	Comments
Oil x-country lines	0	0	0	
Oil Well Pads	0	5	1	Well 1-57 sleeved. 1-49, 2-28, 2-36, 3-25 C-Spools replaced
Water x-country lines	0	0	0	
Water Well Pads	0	1	0	2-34 C-Spool replaced
Gas x-country GLT/MI	0	0	0	
Gas Well Pads	0	1	0	Spool replaced (Well 5-01)

**ACT Table G.1 Endicott Leak/Save and Mechanical Repair Data**

Service	Leaks	Saves	Sleeves	Comments
Oil x-country	0	6	6	K-pad flow line
Oil Well Pads	0	1	1	L-3 Mechanical sleeve. Header abandoned in place
Water x-country	0	0	0	
Water Well Pads	0	0	0	
Gas x-country	0	0	0	
Gas Well Pads	0	0	0	

**ACT Table G.2 Milne Point Leak/Save & Mechanical Repair Data**

Part 2 – Alaska Consolidated Team Performance Unit

<b>Service</b>	<b>Leaks</b>	<b>Saves</b>	<b>Sleeves</b>	<b>Comments</b>
Oil – Well Pad	0	0	0	
Gas – Well Pad	0	0	0	
Disposal Well	0	0	0	

**ACT Table G.3 Northstar Leak/Save and Mechanical Repair Data**

<b>Service</b>	<b>Leaks</b>	<b>Saves</b>	<b>Sleeves</b>	<b>Comments</b>
Oil – Well Pad	0	0	0	
Gas – Well Pad	0	0	0	
Disposal Well	0	0	0	

**ACT Table G.4 Badami Leak/Save and Mechanical Repair Data**

## **Section H 2004 Corrosion Monitoring and Inspection Goals**

### **Section H.1 Endicott**

The increases in the Inter-Island Water Line (IIWL) and well line inspection data for PW/SW service are the result of corrosion activity in a line with extensive pre-existing corrosion. The repairs made to the pigging facilities and resumption of maintenance pigging is expected to minimize further corrosion in the line. This line will continue to be inspected to determine the effectiveness of the corrosion inhibition changes and determine if damage is continuing. Additionally, further changes will be made to the corrosion inhibition and/or biociding programs will be made if the line continues to show degradation.

The well line erosion rate monitoring program will continue.

No significant changes to the corrosion-monitoring program are anticipated.

### **Section H.2 Milne Point**

The 2004 plan will continue to expand the inspection program to provide timely feedback for corrosion control and mechanical integrity.

Analysis of additional production flow lines requiring corrosion inhibition was initiated in 2002. Treatment recommendations will be made in 2004. A major goal for 2004 will be demonstrating the efficacy and optimizing these treatment levels.

A goal in 2003 stated that the Milne Point corrosion evaluation of buried pipe will trial an alternative detection technology that includes fixed monitoring locations of the buried pipe segments. This opportunity did not present itself in 2003, but will remain a goal in 2004 to install these permanent monitoring locations and gain a baseline data set should the opportunity arise. Until such technology proves to be effective, it is planned to carry on with the buried piping excavation program.

A comprehensive review of all Milne Point corrosion monitoring locations will be undertaken in 2004 to determine the need for additional monitoring points.

A study will be made in 2004 to determine the best way forward for corrosion mitigation of remaining uninhibited areas of the field.

### **Section H.3 Northstar**

As previously stated, corrosion monitoring and inspection data will be reviewed as they become available. Changes to the inspection and mitigation activity will be dictated by these data in conjunction with process data. This is an ongoing activity that will continue for a number of years as the corrosion management programs are established at the new production facility.

The recommendation to relocate the chemical injection points to the wellhead will be pursued.

The water disposal system will be evaluated after the mud plant shut down occurs to determine if the corrosion activity subsides and to determine if corrosion activity is more in line with the well inhibited upstream side. Further recommendations will be based on that evaluation.

#### **Section H.4 Badami**

With the shutting in of Badami production for the foreseeable future, monitoring and inspection activity will be limited. However, it is planned to perform a follow-up to the initial shut down inspection in the second half of 2004 to determine if there are any adverse effects from the mothballing. Further recommendations for additional surveys will be made based on that data.

# Appendix 1

## Glossary of Terms





## Glossary of Terms

Term	Definition/Explanation
3 phase production	Unprocessed well head fluids, oil, water, gas – same as OIL
ACT	Alaska Consolidated Team
ATRT	Automated tangential radiographic testing
BAD	Badami
BPXA	BP Exploration (Alaska) Inc.
CCL	Cross country line
CI	Corrosion inhibitor
CIC	Corrosion, Inspection and Chemicals
CIP	Comprehensive Inspection Program
CL	Common line – same as LDF
CMS	Corrosion management system
CPF	Central processing facility
CR	Corrosion rate, mpy
CRA	Corrosion resistant alloy
CRM	Corrosion rate monitoring inspection program
Cross Country lines	Pipelines from the manifold building to major facility
CUI	Corrosion under insulation
CW	Commingled Water
DRT	Digital radiography
END	Endicott
ER	Electrical resistance probe – see corrosion monitoring
ERM	Erosion rate monitoring inspection program
FL	Flow line – same as cross-country
FIP	Frequent inspection program
Frequency C	Continuous
Frequency D	Daily
Frequency H	Hourly
Frequency M	Monthly
Frequency Q	Quarterly
Frequency Y	Yearly/annual
FS	Flow station
G	Gas
GC	Gathering center
GLT	Gas lift transit
GPB	Greater Prudhoe Bay
IIWL	Inter Island Water Line - Endicott
LDF	Large diameter flow line – same as CL
LIS	Lisburne
MFL	Magnetic flux leakage
MI	Miscible injectant
mil	$\frac{1}{1000}$ th of an inch
MIMIR	<b>M</b> echanical <b>I</b> ntegrity <b>M</b> anagement <b>I</b> nformation <b>R</b> epository BPXA corrosion and inspection database
MPI	Main Production Island - Endicott
mpy	Corrosion rate/degradation rate – mils per year
MPU	Milne Point Unit
MW	Mixed water
NDE/NDT	Non-destructive examination/testing
NIA	Niakuk

### Glossary of Terms

<b>Term</b>	<b>Definition/Explanation</b>
NGL	Natural gas liquids
NST	Northstar
OIL	OIL service is 3-phase production service
OWG	Oil, water and gas – 3-phase production
PBU	Prudhoe Bay Unit
PO	Processed oil
ppb	Parts per billion
ppm	Parts per million
PR	Pitting rate, mpy
PTMAC	Point McIntyre
PW	Produced water
RT	Radiographic testing
SDI	Satellite drilling island
Sleeve	Mechanical repair
Slug catcher	First stage pressure vessel of OWG separation facility
STP	Seawater Treatment Plant
SW	Seawater
TRT	Tangential radiographic testing
UT	Ultrasonic testing
VSM	Vertical support member
WAG	Water alternating gas
WL/Well lines	Pipelines from the well head to manifold building
WLC	Weight loss coupon
WPM	Well pad manifold building
WSS	Walking speed survey
WTR	Combined seawater and produced water injection
X-country	Cross country



## Appendix 2

### Work Plan Guide for Performance Metric Reporting





## 2000 Work Plan

### Commitment to Corrosion Monitoring

Phillips Alaska, Inc.  
BP Exploration (Alaska) Inc.

"BP and Phillips will, in consultation with ADEC, develop a performance management program for the regular review of BP's and Phillips' corrosion monitoring and related practices for non-common carrier North Slope pipelines operated by BP or Phillips. This program will include meet and confer working sessions between BP, Phillips and ADEC, scheduled on average twice per year, reports by BP and Phillips of their current and projected monitoring, maintenance and inspection practices to assess and to remedy potential or actual corrosion and other structural concerns related to these lines, and ongoing consultation with ADEC regarding environmental control technologies and management practices."

#### Work Plan Purpose:

The purpose of this work plan is to clearly define the purpose, scope, content, reporting requirements, roles and responsibilities, and milestones/timing for the development and implementation of the Corrosion Monitoring Performance Management Program required by Paragraph II.A.6 of the North Slope Charter Agreement.

#### Corrosion Monitoring Performance Management Program

**Purpose:** To provide for 'the regular review of BP and PAI's corrosion monitoring and related practices for non-common carrier North Slope pipelines' operated by BP or PAI.

'Corrosion Monitoring' specifically refers to the activity of monitoring pipeline corrosion rates via corrosion probes, corrosion coupons, internal pipeline inspections, and external pipeline inspections.

'Related practices' refers to the assessment of corrosion monitoring data and the associated response to the assessment, specifically chemicals, inspection, and repairs.

**Scope:** Non-common carrier North Slope pipelines operated by BP or Phillips Alaska, Inc.

"Non-common carrier pipelines" refer to Non-DOT-regulated pipelines. Included in this designation are cross-country and on-pad pipelines in crude, gas, and other hydrocarbon services, as well as, produced water and seawater service pipelines. In module and inter-module on pad piping are not considered part of the scope of this review program.

**Content:** This Corrosion Monitoring Performance Management Program consists of the following:

1. BP and PAI will "meet and confer" with ADEC twice per year, on average. These sessions will be "working sessions" where BP and PAI will inform ADEC of the following:
  - A. Summary description of the inspection and maintenance practices used to assess and to remedy potential or actual corrosion, or other significant structural concerns relating to these lines, which have arisen from actual operating experience. This description will address overall areas of focus, the rationale for this focus, and the nature of monitoring and related practices used during the time since the last meeting. This description may be brief if strategies/focus areas have not changed since the last meeting.
  - B. Summary overview of ongoing coupon and probe monitoring results.
  - C. Summary overview of chemical optimization activities.
  - D. Summary overview of ongoing internal inspection activities.
  - E. Summary overview of ongoing external inspection activities.
  - F. Summary overview of ongoing structural concerns
  - G. Summary of conclusions drawn and responses taken to remedy potential or actual corrosion concerns relating to these lines.
  - H. Review/discussion of corrosion or structural related spills and incidents
  - I. Review the actions developed by the operator to address any corrosion performance trends that significantly exceed expected parameters.
  - J. Summary of program improvements and enhancements, if applicable.
  - K. Review of annual monitoring report (see below) at the next scheduled semi-annual meeting.

The agenda for these meetings will also include an opportunity for open discussion and an opportunity for ADEC to ask questions, provide feedback, etc.

These meetings will be targeted for April and October of each year, although this timing can be adjusted upon the mutual agreement of BP, PAI, and ADEC. The location of the meetings will alternate between the parties.

2. BP and PAI will submit annual reports to ADEC, which will provide the status of current and projected monitoring activities. These reports will be issued on or before March 31st of each year, and reflect the prior calendar year. The following information will be provided:
  - A. Annual bullet item reporting the progress of the Charter Agreement corrosion related commitment.
  - B. A general overview of the previous year's monitoring activities.
  - C. Metrics that depict coupon and probe corrosion rates.
  - D. Metrics that characterize chemical optimization activities.
  - E. Metrics that depict the number and type of internal/external inspections done, and, as applicable, the corrosion increases/rates and corresponding inspection intervals.
  - F. Metrics that characterize the quantity and type of repairs made in response to the internal/external inspections done per the above paragraph.
  - G. Metrics that depict the numbers and types of corrosion and structural related spills and incidents.
  - H. A forecast of the next year's monitoring activities in terms of focus areas and inspection goals. These forecasts cannot be viewed as binding, as corrosion strategies are dynamic and priorities will change over the course of the year. However, changes in focus will be communicated to ADEC during the semi-annual meetings described above.

Note: These reports will be presented in, and be part of, a comprehensive North Slope Charter Agreement status report.

3. In addition to the semi-annual "meet and confer" working sessions referenced above, BP and PAI will remain accessible to provide "ongoing consultation" to ADEC regarding environmental control technologies and management practices  
 'Environmental Control Technologies' refer to those technologies specifically related to corrosion monitoring and mitigation of the subject pipelines.  
 'Management practices' refer to corrosion monitoring and related practices as defined above.
4. During the semi-annual 'Meet and Confer' working meetings with BP and/or PAI, ADEC may use the services of a corrosion expert(s) (contracted from funds under Charter Commitment paragraph II.A.7) to assist in the review of performance trends and corrosion program features.

5. BP has assigned CIC Manager, R. Woollam/564-4437, and Phillips has assigned Kuparuk Engineering and Corrosion Supervisor M. Cherry and J. Huber/659-7384, to be the contacts responsible for ensuring these commitments are met, including ADEC notification of scheduled times for the semiannual presentations. The ADEC contact for this effort is (Pipeline Integrity Section Manager/S. Colberg/269-3078) who will notify interested personnel of the presentation times, maintain the reports for distribution to the public when requested and coordinate other issues relating to this commitment.

### **Annual Timetable**

March 31<sup>st</sup> Annual Report

April 30<sup>th</sup> 1H Semi-Annual Review (Meet and Confer)

October 31<sup>st</sup> 2H Semi-Annual Review (Meet and Confer)

## Guide for Performance Metric Reporting

### General

- Different metrics show and reveal different aspects of the business and as a consequence there are rarely any 'right' or 'wrong' measures only 'right' or 'wrong' application and usage
- Summary statistics described below may be provided as a data appendix to the annual reports with the more pertinent tables and graphics being contained in the text as appropriate. The intent is not to clutter and interrupt the flow of the text with extraneous data
- Format of data, the order in which it is presented, etc. of each company's annual report may differ from the order presented below, depending on key messages and data context. For example, one company may choose to imbed Leak/Save data into an inspection graph as opposed to presenting the Leak/Save data in standalone tabular format.
- This is an initial document for implementation in the 2001 annual report to ADEC, it should be noted, that the guidelines provided below can and will be adjusted to improve the efficacy of the annual report and reporting mechanism

### Timescale

- Data to be presented on an aggregate annualized basis
- Base year 1995 providing 5 year history before the start of the Charter Agreement and each year's annual report will add to time series starting in 1995

### Equipment Classification

- **Well Line** Pipe work from the well head to the Well Pad Manifold Building, generally, the flow from a single well prior to commingling before transportation to the separation plant
- **Flow Line** Pipe work from the Well Pad Manifold Building to the Separation plant, generally, cross country and off pad pipe work which carries commingled flow to/from a well pad. Also, straight run flow from the wellhead to separation plant, without commingling, is classified at Flow Line pipe work
- **Exceptions** Pipe work not conforming to these basic definitions will be reported by exception

## Service Definitions

- **Three Phase Production (3ø or OWG)** Basic reservoir fluids (O/W/G – oil, water and gas) produced from down hole through to the main separation plants that typically see only see changes in temperature and pressure from reservoir conditions and are therefore essentially un-separated
- **Seawater (SW)** Water sourced typically from the Beaufort Sea that has undergone primary treatment at the Seawater Treatment Plant. Note, that the seawater treatment plants differ across the slope in the primary treatment methods, most importantly oxygen removal, with both production gas and vacuum stripping being employed
- **Produced Water (PW)** The water produced with the primary reservoir 3 phase production after passing through the separation and treatment
- **Commingled Water (CW) or Mixed Water (MW)** Water which has been commingled and is therefore multi-sourced, this is typically a mix of SW and PW although other combinations exist in the operations on the North Slope
- **Gas (G)** Generic term for a number of different gas systems which transport essentially dry gas between facilities including fuel gas, lift gas and miscible injectant
- **Processed Oil (PO)** The oil/hydrocarbon produced with the primary reservoir 3 phase production after separation and treatment, this is primarily black oil but could include black oil plus NGL's

## Basic Summary Statistics

- **Distribution** The data is fundamentally of log-normal distribution, with a lower limit of zero or no-change and potentially unlimited upper extent
- **Count** A count of the number of activities completed i.e. coupons pulled in a given year
- **Average** The average or mean for the criteria being summarized i.e. average corrosion rate
- **Target Value** The target value against which non-conformance, see below, is reported
- **Number Non-conformant** The number of items not conforming to the control criteria i.e. the number of coupons exceeding the control value
- **Percentage Non-conformance** The percentage not conforming to the control value as a percentage of the total



### Weight Loss Coupon Data

Table below summarizes the reporting of weight loss coupon data for the major fields on the North Slope

	<b>Well Lines</b>	<b>CCL/FL</b>
3 ø Production	All	All
Seawater	GPB	All
Prod. Water	GPB	GPB
Commingle Water	All	All

The data sets to be provided for both general corrosion rates and pitting rates are,

- Count of coupons
- Average corrosion rate
- Number non-conformant
- % Conformant i.e. 1 minus the % non-conformant

A corrective action list for non-conformant flow lines (FL/LDF/CCL/CLs) will also be provided.

### Internal Inspection Data

Table below summarizes the reporting of internal corrosion inspection data for the major fields on the North Slope

	<b>Well Lines</b>	<b>CCL/FL</b>
3 ø Production	All	All
Commingle Water	All	All

Note that no distinction will be made between water services across the North Slope since in many cases the service is variable making meaningful analysis and aggregation difficult.

- The data sets to be provided for internal inspection are,
- Count of inspections
- Number of increases on repeat inspection locations
- Percentage of increases on repeat inspections

A corrective action list for flow lines (FL/LDF/CCL/CLs) with inspection increases will also be provided.

### **Corrosion Inhibition**

The corrosion inhibition program is to be reported as the target and actual total annual gallons and gallons per day, and as concentration, ppm, based on a field wide average.

### **External Corrosion Inspection**

External corrosion inspection program is to be reported as an aggregate of all piping systems without distinction or differentiation of service and equipment type with a summary of the overall program status.

The data sets to be provided for external inspection are,

- Count of inspected location
- Number of corroded locations
- Percentage of inspection locations corroded

### **Repair and Leak Statistics**

The repair and leak/spill statistics to be reported for each year plus the historical trend back to 1995 consistent with other performance metrics. The basic definitions,

**Leak/Spill** An agency reportable leak/spill for the pipelines covered under the Charter Agreement which was caused by corrosion and/or erosion

**Save** A location which required repair action as a result of corrosion and/or erosion damage but which was found through inspection prior to causing a leak/spill

The data sets to be provided for Repair/Leak statistics,

- Count of Leaks/Saves by flow line and well lines
- Summary of leak/spill causes

### **Below Grade Piping**

The data sets to be provided for Below Grade Piping (BGP) program,

- Number of segments/crossings inspected broken out by inspection method
- Number with anomalies and severity of anomaly

Results of casing digs, visual casing inspections and casing clean-out to be reported as appropriate.

### **Other Programs**

Reporting of ER probe, smart pigging, maintenance pigging, structural issues, and details of individual spill incidents to be reported as dictated by the current year's program activity.



## Appendix 3

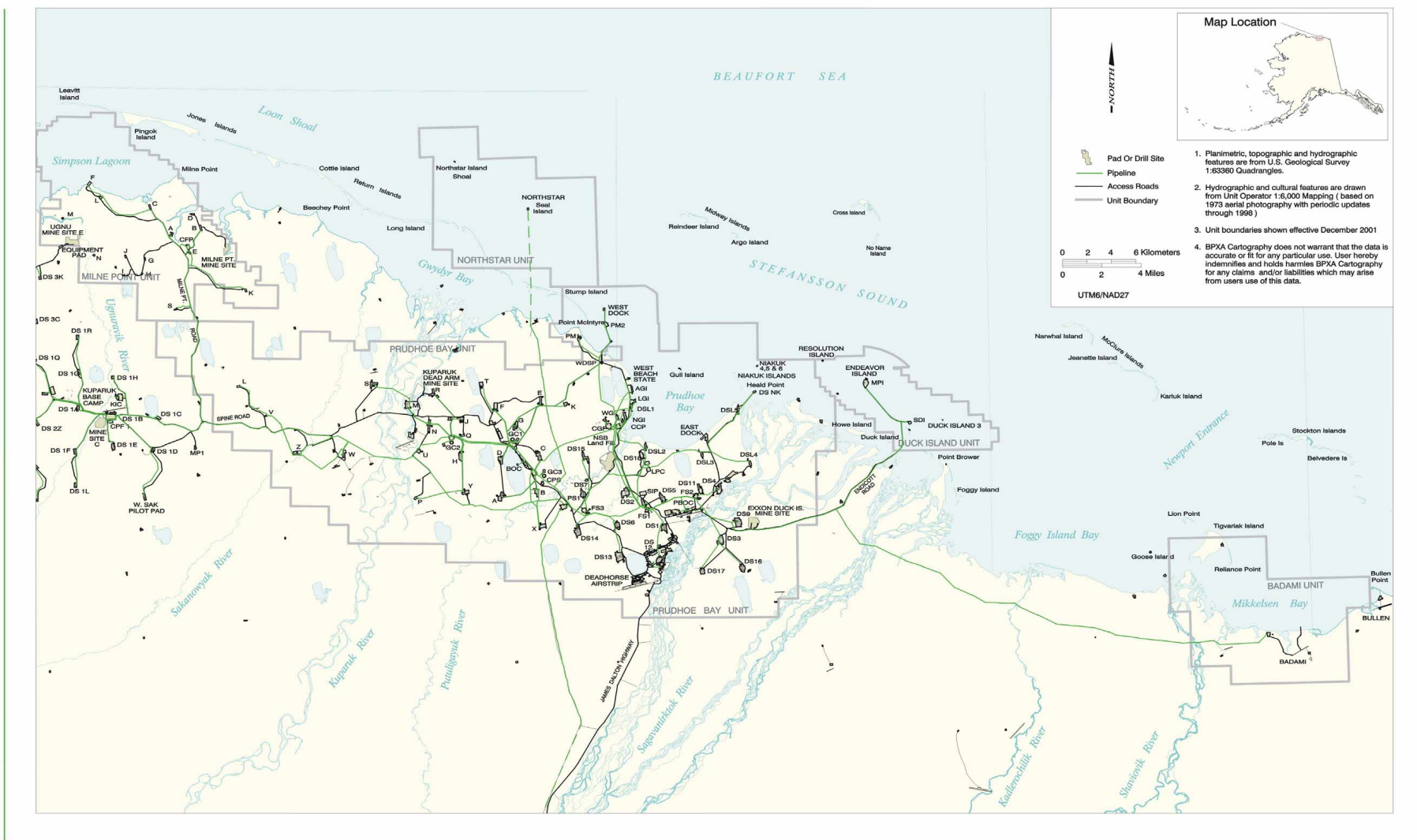
- (a) Map of the North Slope
- (b) North Slope Oil Field Facility and Piping Summary







## BPXA OPERATING UNITS - NORTH SLOPE, ALASKA



BPXA / Cartography / 03.02 / b13964c.dgn

This page is intentionally blank



<b>BP North Slope Operations</b>		<b>Field Data (current 1/01)</b>
Greater Prudhoe Bay	Field Area	150,000 acres
	Original Oil in Place (Gross)	25 billion barrels
	Original Gas in Place (Gross)	47 trillion Std. Cu Ft
	Oil Production Wells	1,080
	Gas Injection Wells	36
	Water Injection Wells	174
	Major Separation Plants	6
	Major Gas Handling Plants	2
	Major Water Handling Plants	3
	Miles of Pipelines (approximate)	1,300
Midnight Sun	Field Area	3,000 acres
	Original Oil in Place (Gross)	0.06 billion barrels
	Original Gas in Place (Gross)	trillion Std Cu Ft
	Oil Production Wells	2
	Water Injection Wells	1
	Miles of Pipelines (approximate)	4
Aurora	Field Area	10,000 acres
	Original Oil in Place (Gross)	billion barrels
	Original Gas in Place (Gross)	trillion Std Cu Ft
	Oil Production Wells	5
	Miles of Pipelines (approximate)	1
Pt. McIntyre	Field Area	8,000 acres
	Original Oil in Place (Gross)	0.8 billion barrels
	Original Gas in Place (Gross)	0.9 trillion Std Cu Ft
	Oil Production Wells	59
	Gas Injection Wells	1
	Water Injection Wells	15
	Miles of Pipelines (approximate)	6
Lisburne	Field Area	30,000 acres
	Original Oil in Place (Gross)	1.8 billion barrels
	Original Gas in Place (Gross)	trillion Std Cu ft
	Oil Production Wells	74
	Gas Injection Wells	4
	Major Separation Plants	1
	Miles of Pipelines (approximate)	27
Niakuk & Western Niakuk	Field Area	1,900 acres
	Original Oil in Place (Gross)	billion barrels
	Original Gas in Place (Gross)	trillion Std Cu Ft
	Oil Production Wells	18
	Water Injection Wells	7
	Miles of Pipelines (approximate)	6

BP North Slope Operations		Field Data (current 1/01)
Milne Point	Field Area	36,454 acres
	Original Oil in Place (Gross)	0.92 billion barrels
	Oil Production Wells	107
	Gas/Water Injection Wells	59
	Source Water Wells	8
	Major Separation Plants	1
	Miles of Pipelines (approximate)	55
Schrader Bluff	Field Area	28,000 acres
	Original Oil in Place (Gross)	1.97 billion barrels
	Oil Production Wells	49
	Gas\Water Injection Wells	14
	Source Water Wells	3
	Miles of Pipelines (approximate)	15
Eider	Field Area	300 acres
	Original Oil in Place (Gross)	0.013 billion barrels
	Original Gas in Place (Gross)	0.052 trillion Std Cu Ft
	Oil Production Wells	1
	Gas Injection Wells	1
	Miles of Pipelines (approximate)	.5
Endicott	Field Area	8,800 acres
	Original Oil in Place (Gross)	billion barrels
	Original Gas in Place (Gross)	1.4 trillion Std Cu Ft
	Oil Production Wells	47
	Gas Injection Wells	5
	Water Injection Wells	21
	Major Separation Plants	1
	Miles of Pipelines (approximate)	52
Sag Delta North	Field Area	380 acres
	Original Oil in Place (Gross)	0.014 billion barrels
	Oil Production Wells	2
	Gas Injection Wells	2
	Miles of Pipelines (approximate)	.5
Badami	Original Oil in Place (Gross)	0.160 billion barrels
	Oil Production Wells	6
	Gas Injection Wells	2
	Major Separation Plants	1
	Miles of Pipelines (approximate)	50
Northstar (current 3/02)	Field Area	38,000 acres
	Original Oil in Place (Gross)	.176 billion barrels
	Oil Production Wells	4
	Disposal Injection Wells	1
	Gas Injection Wells	2
	Major Separation Plants	1
	Miles of Pipelines (approximate)	30

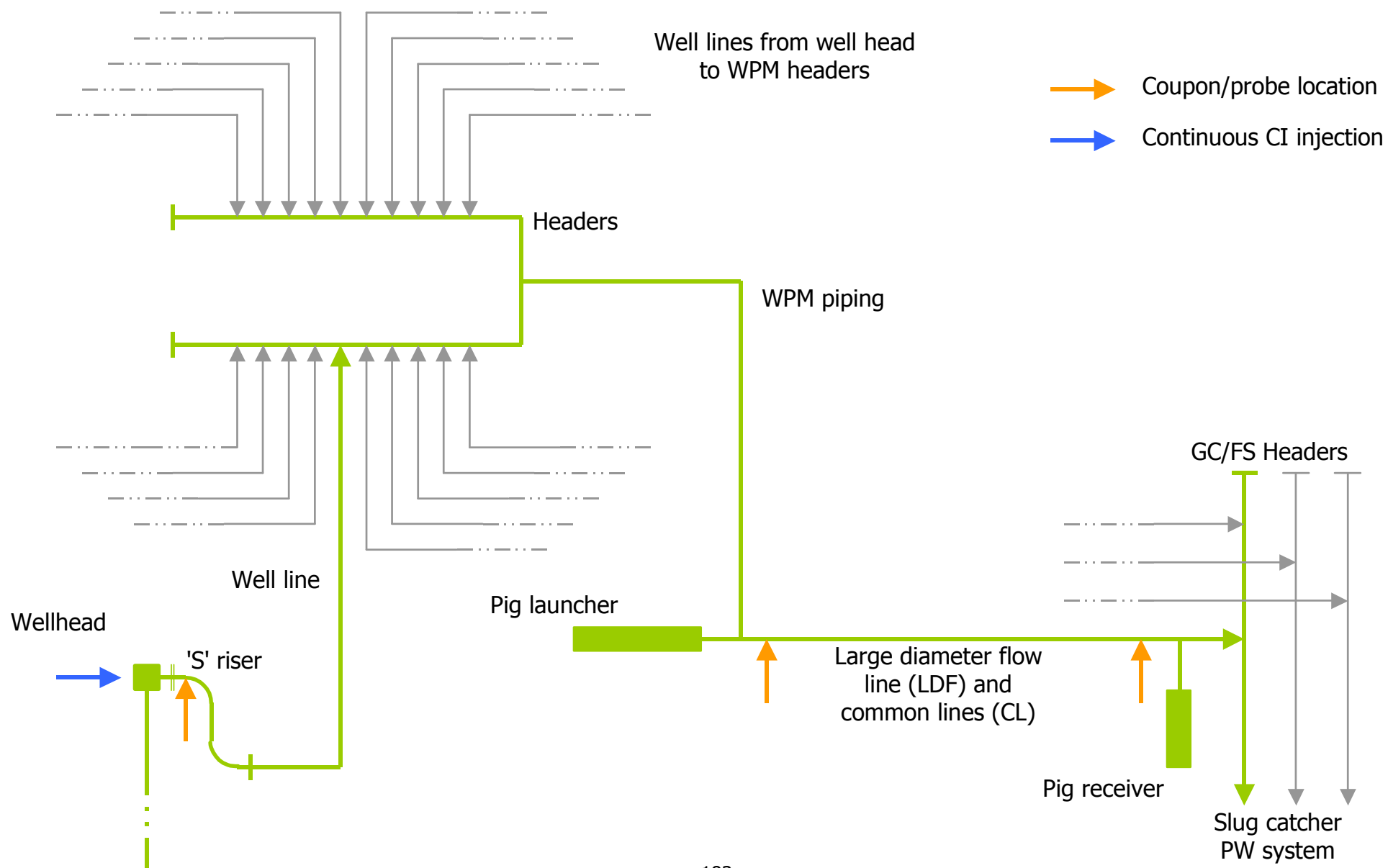
## **Appendix 4**

### **Facilities Schematic**





# Facility Schematic



This page is intentionally blank

## Appendix 5

### Data Tables







## Introduction

With the introduction of single-operatorship at Greater Prudhoe Bay one of the major problems faced by the Corrosion Inspection and Chemical (CIC) Group was the integration of two historical data sets for inspection, corrosion monitoring and corrosion mitigation information.

There has been a significant investment in resources in order to bring together these two different histories from incompatible databases based on early 1990's technology.

As of the end of 2002, the inspection program and corrosion-monitoring program have largely been integrated into a single database on an Oracle platform with a user interface in VisualBasic.

The database development effort has involved a dedicated team of software developers and database administration but also significant resources from within the CIC Group. The program is currently a "work in progress" and in 2003 BP/CIC will continue work on the development of chemical management, electronic data recording, tank and vessel, and standard reporting modules.

The data is continuously monitored for integrity, quality and consistency; as a consequence any errors detected are corrected as they are found. In addition, as better analysis tools become available through further integration then records are amended to reflect the improved level of analysis.

As a result of the ongoing quality effort and the tracking of production/service changes, this is a 'live' database and therefore as the system changes then the records returned will change. The following are some of reasons why returned values change through time,

**Quality Control and Audit** A fundamental design philosophy for the database was that errors should be corrected through time as they are discovered. Therefore as the database is used and the quality control rules and procedures applied, data-entry, translation and record-keeping errors are eliminated.

**Equipment Service Changes** The database tracks active, in or out-of-use equipment, and equipment service changes. As a piece of equipment moves through different services and different status, then the data in the database tracks the equipment status.

**Transition Issues** As noted above, the two historical databases, heritage East and heritage West, were incompatible with very different structures and data fields. Therefore these have had to be translated to the new system. As the quality control and audit tools are applied to the translated data, error and mistranslations are removed.

**Time** The database is in active use with data being added everyday, given that there is sometimes a time delay between the reporting date and entry date then the data totals can and do change.

BU	Equip	Service	Metric	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
GPB	FL	OIL	WLC	815	990	1,017	1,435	1,562	1,602	1,496	1,528	1,455	1,309	1,355	1,240
GPB	FL	OIL	Ave CR	3.2	3.1	1.9	1.41	0.85	0.50	0.49	0.32	0.42	0.34	0.33	0.43
GPB	FL	OIL	SD CR	8.6	10.4	5.1	6.94	3.94	2.07	3.75	0.57	0.84	0.90	0.67	2.47
GPB	FL	OIL	WLC < 2	628	759	874	1,296	1,474	1,556	1,466	1,514	1,415	1,288	1,342	1,234
GPB	FL	OIL	% WLC < 2mpy	77%	77%	86%	90%	94%	97%	98%	99%	97%	98%	99%	100%
GPB	FL	PW/SW	WLC	81	106	154	198	184	195	171	181	161	131	137	129
GPB	FL	PW/SW	Ave CR	3.5	6.6	7.4	3.18	2.73	0.87	1.44	1.41	1.61	1.86	3.11	1.54
GPB	FL	PW/SW	SD CR	4.4	9.1	15.4	9.52	6.15	1.77	3.72	2.42	2.77	2.54	5.39	2.63
GPB	FL	PW/SW	WLC < 2	43	42	86	162	140	168	139	147	124	89	90	98
GPB	FL	PW/SW	% < 2mpy	53%	40%	56%	82%	76%	86%	81%	81%	77%	68%	66%	76%
GPB	FL	PO	WLC		16	23	24	34	44	32	34	36	22	28	40
GPB	FL	PO	Ave CR		0.4	0.6	0.13	0.23	0.13	0.16	0.14	0.17	0.08	0.09	0.11
GPB	FL	PO	SD CR		0.4	0.4	0.17	0.29	0.19	0.11	0.05	0.07	0.06	0.03	0.04
GPB	FL	PO	WLC < 2		16	23	24	34	44	32	34	36	22	28	40
GPB	FL	PO	% < 2 mpy		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
GPB	WL	OIL	WLC	6,894	5,716	5,057	5,330	6,670	6,883	6,491	6,267	6,321	4,921	5,367	4,732
GPB	WL	OIL	Ave CR	3.4	4.2	2.9	2.73	2.22	0.93	0.71	0.55	0.74	0.64	0.57	0.47
GPB	WL	OIL	SD CR	7.8	7.9	4.5	6.94	6.16	2.33	3.68	1.20	1.49	1.60	1.12	1.18
GPB	WL	OIL	WLC < 2	4,588	3,091	2,901	3,788	5,080	6,104	6,107	6,021	5,833	4,593	5,029	4,541
GPB	WL	OIL	% < 2 mpy	67%	54%	57%	71%	76%	89%	94%	96%	92%	93%	94%	96%
GPB	WL	Majority PW	WLC	531	514	662	829	976	1,073	966	740	699	659	464	296
GPB	WL	Majority PW	Ave CR	5.8	3.5	1.9	0.80	0.86	0.35	2.44	0.47	0.27	1.43	0.29	0.11
GPB	WL	Majority PW	SD CR	12.8	4.8	1.9	1.19	8.68	2.26	12.05	1.64	0.43	8.55	0.88	0.15
GPB	WL	Majority PW	WLC < 2	345	307	467	760	947	1,047	886	716	690	598	449	296
GPB	WL	Majority PW	% WLC < 2 mpy	65%	60%	71%	92%	97%	98%	92%	97%	99%	91%	97%	100%
GPB	WL	100% PW	WLC	282	304	286	485	604	717	721	524	459	473	332	252
GPB	WL	100% PW	Ave CR	4.6	4.2	2.1	0.81	1.10	0.35	2.90	0.40	0.30	1.92	0.29	0.11
GPB	WL	100% PW	SD CR	9.3	5.3	2.0	1.19	10.98	2.62	13.64	1.50	0.51	10.05	0.97	0.15
GPB	WL	100% PW	WLC < 2	190	158	192	447	589	703	658	512	450	416	323	252
GPB	WL	100% PW	% WLC < 2mpy	67%	52%	67%	92%	98%	98%	91%	98%	98%	88%	97%	100%
GPB	WL	Majority SW	WLC	434	410	384	317	162	56	44	82	98	44	25	17
GPB	WL	Majority SW	Ave CR	2.0	13.0	6.5	2.63	3.25	0.65	0.96	1.82	1.78	6.01	6.58	0.78
GPB	WL	Majority SW	SD CR	5.5	16.1	7.5	3.86	5.26	1.20	1.14	2.36	2.77	6.88	5.27	0.72
GPB	WL	Majority SW	WLC < 2	382	103	135	203	110	53	38	61	78	16	7	16
GPB	WL	Majority SW	% WLC < 2mpy	88%	25%	35%	64%	68%	95%	86%	74%	80%	36%	28%	94%
GPB	WL	100% SW	WLC	184	194	176	189	78	52	44	70	86	16	21	17
GPB	WL	100% SW	Ave CR	2.6	18.2	5.7	2.80	2.86	0.68	0.96	1.82	1.89	1.92	7.46	0.78
GPB	WL	100% SW	SD CR	7.1	19.0	8.0	4.43	5.39	1.24	1.14	2.50	2.93	1.07	5.28	0.72
GPB	WL	100% SW	WLC < 2	160	38	81	130	54	49	38	52	68	12	5	16
GPB	WL	100% SW	% WLC < 2mpy	87%	20%	46%	69%	69%	94%	86%	74%	79%	75%	24%	94%

**Table 5.1** GPB Flow and Well Line General Corrosion Rate Data Summary

This page is intentionally blank

BU	Equip	Service	Metric	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
GPB	FL	OIL	WLC	815	990	1,017	1,435	1,562	1,602	1,496	1,528	1,455	1,309	1,355	1,240
GPB	FL	OIL	Ave P CR	7.2	5.6	4.4	9.48	7.80	6.86	2.96	1.63	1.89	1.26	0.73	0.65
GPB	FL	OIL	SD P CR	22.6	15.3	14.2	24.31	15.00	14.03	6.67	6.14	7.69	10.52	3.91	8.57
GPB	FL	OIL	P WLC < 20	717	905	960	1,307	1,465	1,545	1,470	1,505	1,422	1,294	1,334	1,238
GPB	FL	OIL	% P WLC <20mpy	88%	91%	94%	91%	94%	96%	98%	98%	98%	99%	98%	100%
GPB	FL	PW/SW	WLC	81	106	154	198	184	195	171	181	161	131	137	129
GPB	FL	PW/SW	Ave P CR	8.5	15.8	17.3	17.03	14.40	15.26	11.36	5.31	6.47	9.37	13.12	7.89
GPB	FL	PW/SW	SD P CR	8.5	5.4	8.6	6.60	5.40	4.10	3.01	2.53	2.32	0.91	0.01	0.01
GPB	FL	PW/SW	P WLC < 20	80	97	140	190	178	195	170	181	161	131	134	129
GPB	FL	PW/SW	% P WLC <20mpy	99%	92%	91%	96%	97%	100%	99%	100%	100%	100%	98%	100%
GPB	FL	PO	WLC		16	23	24	34	44	32	34	36	22	28	40
GPB	FL	PO	Ave P CR		0.5	0.7	1.88	2.56	3.73	2.19	1.26	1.44	1.05	0.77	0.35
GPB	FL	PO	SD P CR		1.2	2.5	3.42	4.64	4.31	5.65	2.43	3.49	3.47	3.92	2.21
GPB	FL	PO	P WLC < 20		16	23	24	34	44	31	34	36	22	26	40
GPB	FL	PO	% P WLC <20mpy		100%	100%	100%	100%	100%	97%	100%	100%	100%	93%	100%
GPB	WL	OIL	WLC	6,894	5,716	5,057	5,330	6,670	6,883	6,491	6,267	6,321	4,921	5,367	4,737
GPB	WL	OIL	Ave P CR	7.3	9.3	5.1	11.56	11.85	5.25	3.23	2.79	3.30	1.96	1.70	1.43
GPB	WL	OIL	SD P CR	22.4	24.0	14.2	32.25	29.20	14.64	9.95	7.88	10.13	6.42	5.60	5.21
GPB	WL	OIL	P WLC < 20	5,959	5,048	4,723	4,658	5,778	6,600	6,326	6,141	6,132	4,815	5,291	4,691
GPB	WL	OIL	% P WLC <20mpy	86%	88%	93%	87%	87%	96%	97%	98%	97%	98%	99%	99%
GPB	WL	Majority PW	WLC	531	514	662	829	976	1,073	966	740	699	659	464	302
GPB	WL	Majority PW	Ave P CR	34.1	24.7	15.8	20.18	15.02	9.65	20.65	8.87	4.65	6.69	2.95	1.14
GPB	WL	Majority PW	SD P CR	41.1	31.9	27.1	29.05	29.64	28.96	58.54	26.07	9.75	17.52	8.97	3.35
GPB	WL	Majority PW	P WLC < 20	258	294	499	574	802	968	807	674	670	579	452	301
GPB	WL	Majority PW	% P WLC < 20mpy	49%	57%	75%	69%	82%	90%	84%	91%	96%	88%	97%	100%
GPB	WL	100% PW	WLC	282	304	286	485	604	717	721	524	459	473	332	252
GPB	WL	100% PW	Ave P CR	33.1	23.3	13.3	20.74	15.15	7.60	22.23	7.13	4.68	8.13	2.77	1.06
GPB	WL	100% PW	SD P CR	38.3	31.0	20.1	30.96	30.19	19.29	64.18	25.49	11.14	19.97	9.69	3.36
GPB	WL	100% PW	WLC < 20	131	174	222	331	500	659	603	489	438	401	324	251
GPB	WL	100% PW	% P WLC <20mpy	46%	57%	78%	68%	83%	92%	84%	93%	95%	85%	98%	100%
GPB	WL	Majority SW	WLC	434	410	384	317	162	56	44	82	98	44	25	17
GPB	WL	Majority SW	Ave P CR	4.7	17.3	9.5	11.36	16.88	1.50	1.55	5.62	6.61	18.80	29.33	10.18
GPB	WL	Majority SW	SD P CR	15.6	44.3	14.2	15.43	23.11	4.52	2.31	8.16	10.40	18.59	27.35	21.16
GPB	WL	Majority SW	P WLC < 20	404	320	331	263	115	55	44	80	92	24	15	14
GPB	WL	Majority SW	% P WLC < 20mpy	93%	78%	86%	83%	71%	98%	100%	98%	94%	55%	60%	82%
GPB	WL	100% SW	WLC	184	194	176	189	78	52	44	70	86	16	21	17
GPB	WL	100% SW	Ave P CR	5.2	13.3	7.8	9.09	10.10	0.54	1.55	5.24	5.57	9.13	31.62	10.18
GPB	WL	100% SW	SD P CR	18.9	18.8	12.1	13.41	19.87	2.18	2.31	8.49	6.38	7.30	29.49	21.16
GPB	WL	100% SW	P WLC < 20	172	157	156	162	62	52	44	68	82	14	12	14
GPB	WL	100% SW	% P WLC <20mpy	93%	81%	89%	86%	79%	100%	100%	97%	95%	88%	57%	82%

Table 5.2 GPB Flow and Well Line Pitting Rate Data Summary

This page is intentionally blank

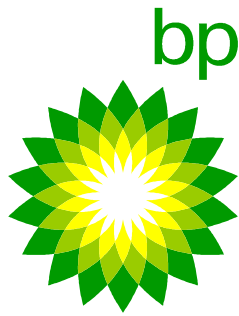
<b>BU</b>	<b>Type</b>	<b>Service</b>	<b>Result</b>	<b>1995</b>	<b>1996</b>	<b>1997</b>	<b>1998</b>	<b>1999</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>
GPB	FL	OIL	I	367	935	1,167	407	239	67	60	101	152
GPB	FL	OIL	NC	15,239	15,795	16,618	14,938	12,125	8,213	7,181	8,858	9,087
GPB	FL	OIL	NL	3,641	2,119	1,981	465	380	148	1,715	1,876	1,951
<b>GPB</b>	<b>FL</b>	<b>OIL</b>	<b>Total</b>	<b>19,247</b>	<b>18,849</b>	<b>19,766</b>	<b>15,810</b>	<b>12,744</b>	<b>8,428</b>	<b>8,956</b>	<b>10,835</b>	<b>11,190</b>
GPB	FL	WTR	I	171	123	153	191	71	17	43	138	170
GPB	FL	WTR	NC	1,163	1,076	1,123	1,555	1,559	717	1,093	1,142	1,482
GPB	FL	WTR	NL	422	115	136	87	77	61	343	360	218
<b>GPB</b>	<b>FL</b>	<b>WTR</b>	<b>Total</b>	<b>1,756</b>	<b>1,314</b>	<b>1,412</b>	<b>1,833</b>	<b>1,707</b>	<b>795</b>	<b>1,479</b>	<b>1,640</b>	<b>1,870</b>
<b>GPB</b>	<b>FL</b>	<b>Total</b>	<b>Total</b>	<b>21,003</b>	<b>20,163</b>	<b>21,178</b>	<b>17,643</b>	<b>14,451</b>	<b>9,223</b>	<b>10,435</b>	<b>12,475</b>	<b>13,060</b>
GPB	WL	OIL	I	642	917	875	605	311	262	213	274	322
GPB	WL	OIL	NC	2,462	3,520	3,411	4,107	3,648	4,142	5,518	7,144	6,577
GPB	WL	OIL	NL	963	1,787	1,980	707	575	527	2,468	3,522	2,287
<b>GPB</b>	<b>WL</b>	<b>OIL</b>	<b>Total</b>	<b>4,067</b>	<b>6,224</b>	<b>6,266</b>	<b>5,419</b>	<b>4,534</b>	<b>4,931</b>	<b>8,199</b>	<b>10,940</b>	<b>9,186</b>
GPB	WL	WTR	I	222	262	201	210	74	126	77	123	149
GPB	WL	WTR	NC	1,018	1,525	1,073	1,613	1,403	1,736	1,276	1,135	1,319
GPB	WL	WTR	NL	614	360	635	223	176	260	486	516	360
<b>GPB</b>	<b>WL</b>	<b>WTR</b>	<b>Total</b>	<b>1,854</b>	<b>2,147</b>	<b>1,909</b>	<b>2,046</b>	<b>1,653</b>	<b>2,122</b>	<b>1,839</b>	<b>1,774</b>	<b>1,828</b>
<b>GPB</b>	<b>WL</b>	<b>Total</b>	<b>Total</b>	<b>5,921</b>	<b>8,371</b>	<b>8,175</b>	<b>7,465</b>	<b>6,187</b>	<b>7,053</b>	<b>10,038</b>	<b>12,714</b>	<b>11,014</b>
<b>GPB</b>	<b>Total</b>	<b>Total</b>	<b>Total</b>	<b>26,924</b>	<b>28,534</b>	<b>29,353</b>	<b>25,108</b>	<b>20,638</b>	<b>16,276</b>	<b>20,473</b>	<b>25,189</b>	<b>24,074</b>

Table 5.3 GPB Flow and Well Line Inspection Data

This page is intentionally blank







Corrosion, Inspection and Chemical (CIC) Group  
BP Exploration (Alaska) Inc.  
900 E Benson Boulevard  
Anchorage  
Alaska

© 2004 BP Exploration (Alaska) Inc.